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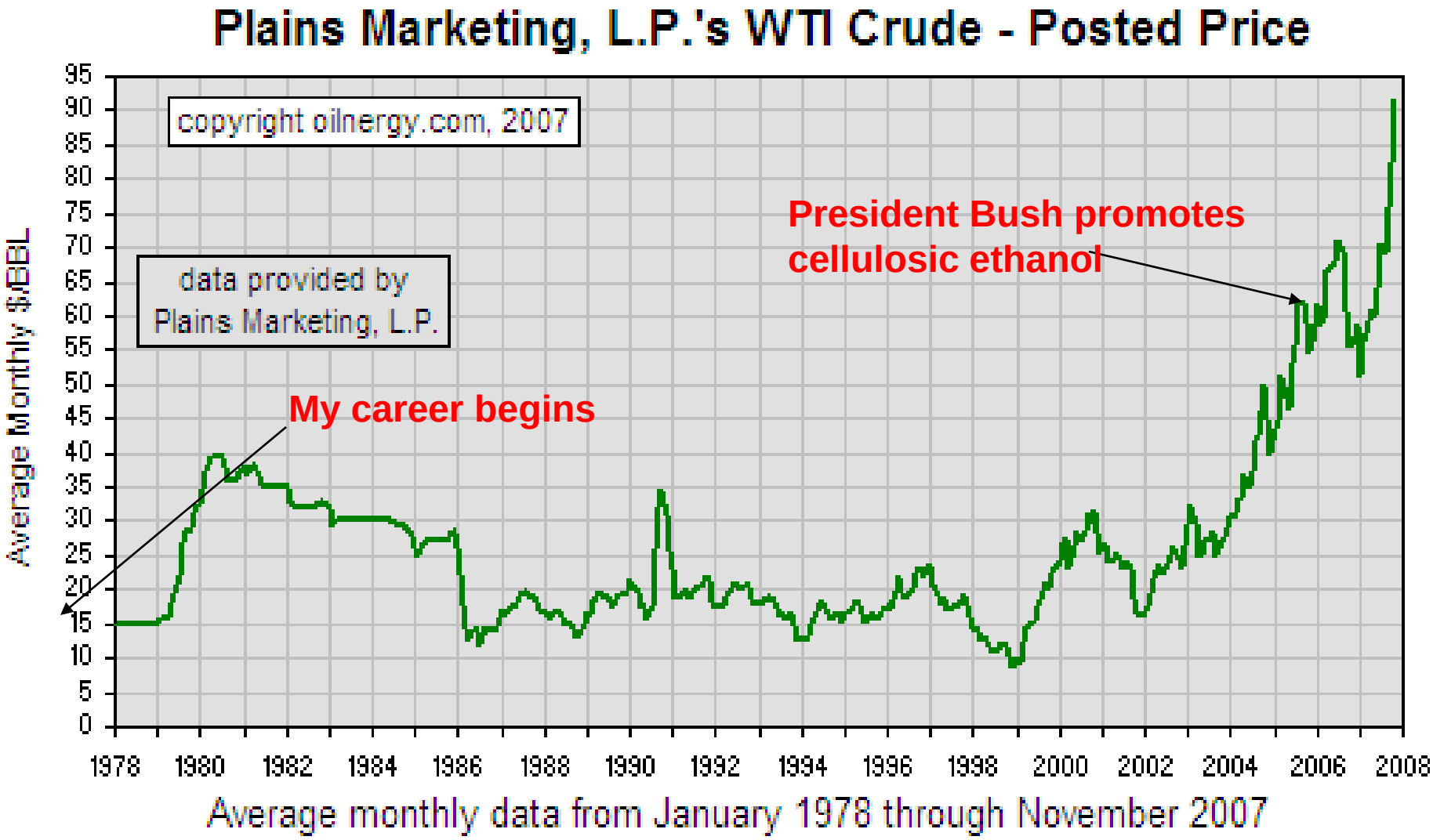
# *BIOFUELS, FOOD, ECONOMIC DEVELOPMENT & THE ENVIRONMENT: DESIGNING THE BIOFUELS FUTURE*

**Bruce E. Dale**
**Distinguished University Professor**
**Dept. of Chemical Engineering & Materials Science**
**Michigan State University**
**www.everythingbiomass.org**

**USAIN Conference**
**April 27-30**
**Wooster, Ohio**

# 1978 – 2008 CRUDE OIL PRICES

## IT PAYS TO BE PATIENT (OR STUBBORN)



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# Why Cellulosic Ethanol Is Nearer

- Plant matter energy content is much less expensive than oil's energy content
- Billions of tons of cellulosic biomass available, and we could grow much more…land is not an issue
- Technology to convert inexpensive biomass energy content to liquid fuels is improving
  - Federal & state research support: at least $1 billion
  - Venture capital & other private funds: at least $2 billion
  - Large scale plants being built (including 1 in Michigan) $2 billion
- Infrastructure for ethanol distribution & use is improving
- Megatrends for oil are negative-trends for biomass ethanol are largely positive
- Political will to make it happen—both parties
- Active promotion of ethanol by auto companies, esp. GM
- LOTS of money to be made with $100/barrel oil

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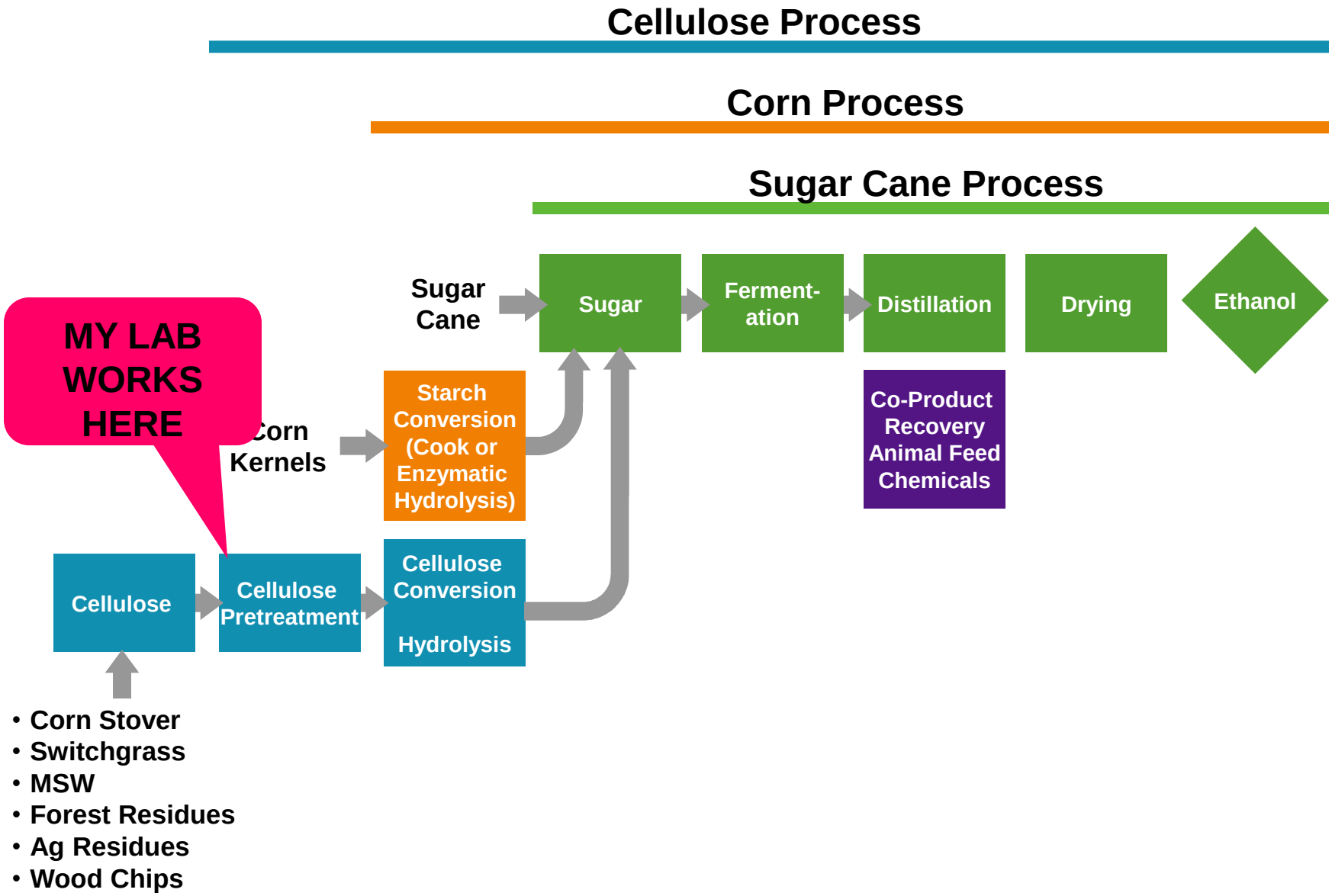
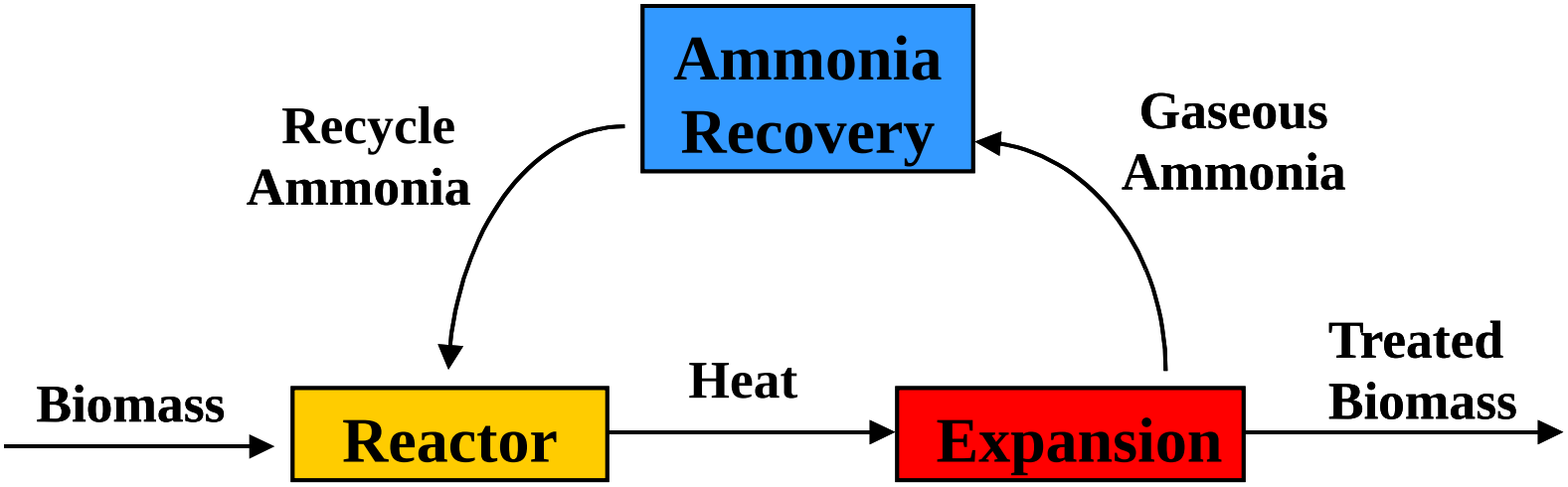
# Ethanol Production Flowchart



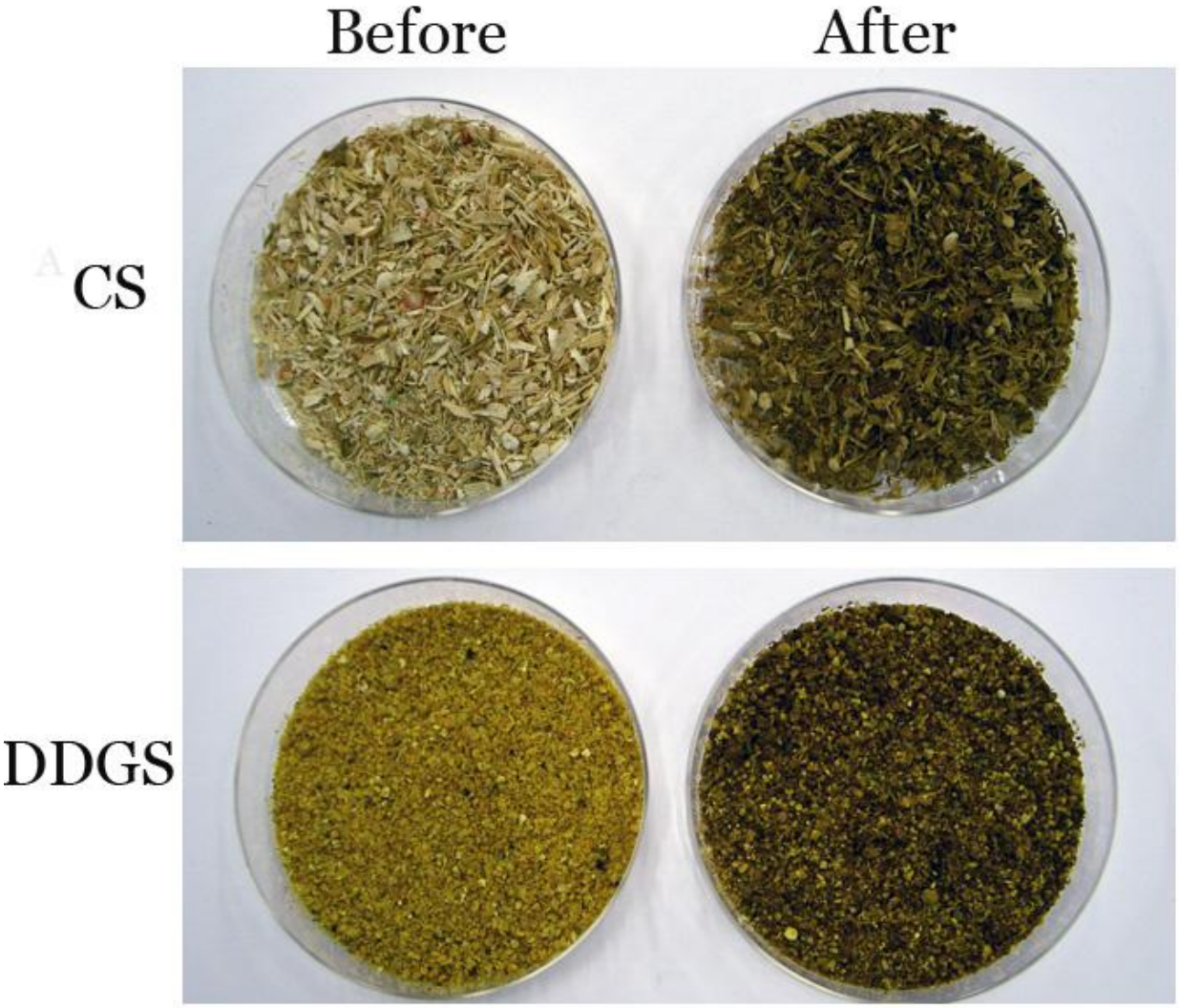
# How does AFEX pretreatment work?




**AFEX process description and properties**

- hot, concentrated ammonia:water mixtures, short reaction time
- rapid pressure release ends treatment, cools system
- little biomass degradation, high yields, residual ammonia value
- "dry to dry" process—very high concentrations possible
- Typical process conditions
  - Pressure 15-25 atm
  - Temperature 70-140 C
  - Residence time 5-15 minutes
  - Ammonia: dry biomass loading (0.3 -2.0 to 1) (w/w)
  - Water: dry biomass content (0.2 – 2.5 to 1) (w/w)

# Before and After AFEX



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# Ethanol from AFEX Treated and Untreated Corn Stover (15 IU enzyme /gm glucan)

**AFEX treated stover in fed batch SSF at 24% solids loading**

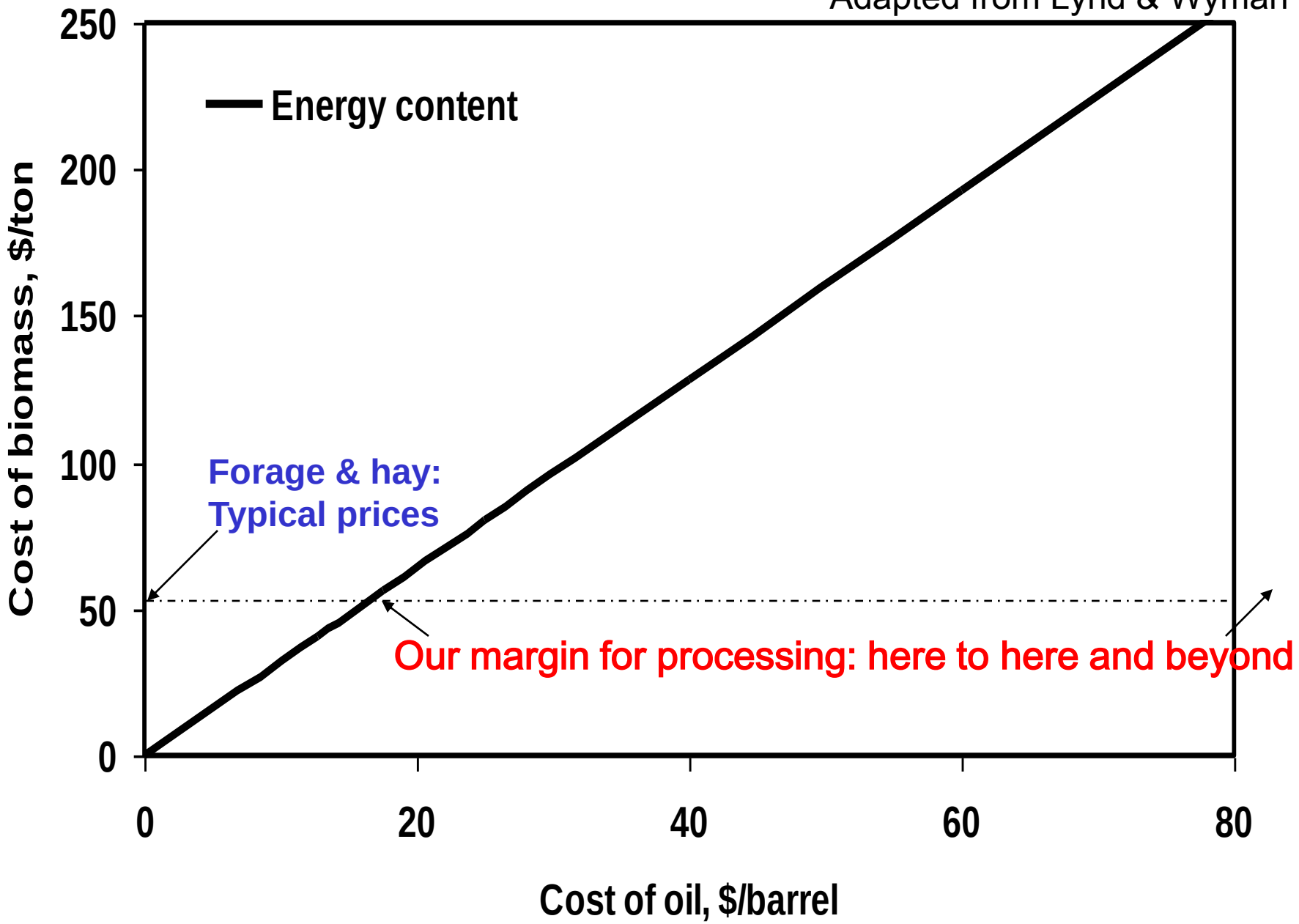
**Untreated stover in SSF 24% solids loading**


**Doesn't flow worth a dang**

**Flows very easily**

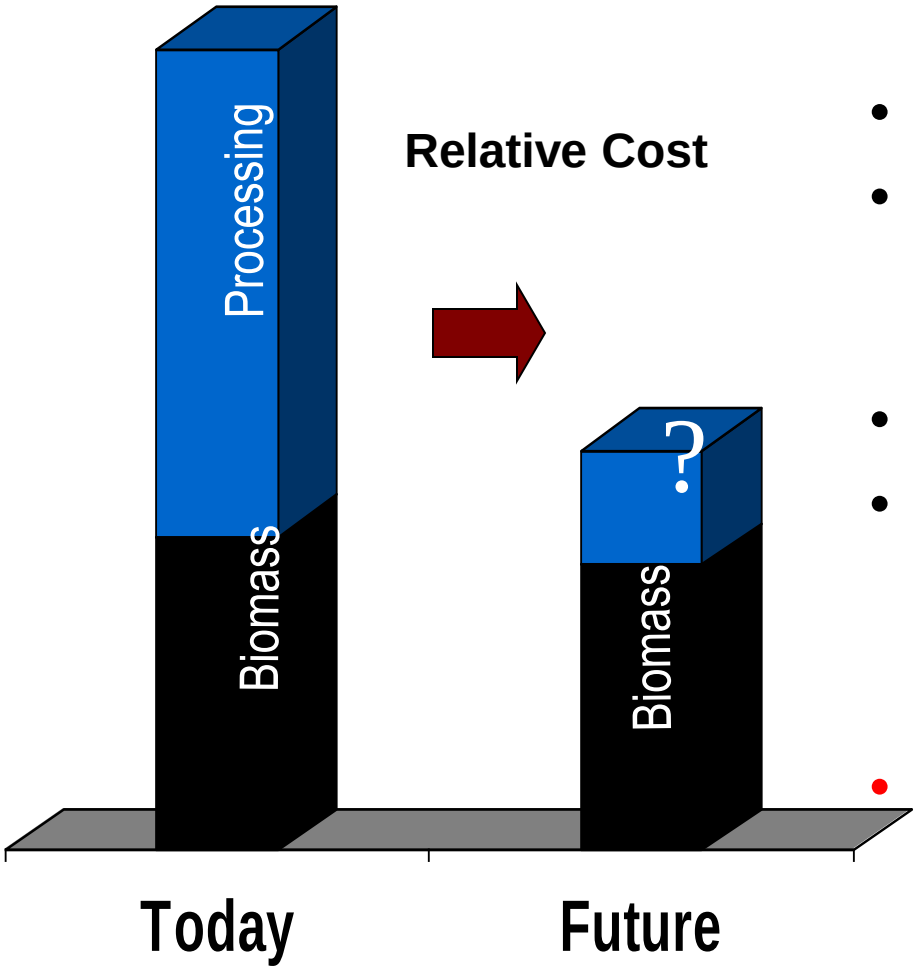
***Dark appearance is deceptive- caused by autoclaving & media***

Adapted from Lynd & Wyman




*Plant material is much, much cheaper than oil on both energy & mass basis*

# Impact of Processing Improvements: The Future of Cellulosic Biomass Conversion




Adapted from J. Stoppert, 2005

- Processing dominant now:
  - -yield, concentration & rate
- Biomass costs should be stable
- Processing costs controlled by pretreatment, enzymes & fermentation
- Processing costs will decrease
- Two ways to do this:
  1. "Learning by doing" in large scale plants
  2. Applied (cost focused) research
- Much more attractive future
  - Domestically produced fuels
  - Environmental improvements
  - Rural/regional/national economic development

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# Cellulosic Ethanol Gains Momentum

| Company/ Location | Feedstock | Pretreat? | Conversion Process | Size |
|---|---|---|---|---|
| Abengoa/ Kansas | Wheat straw, switchgrass | Steam explosion | Enzymes, fermentation | 11.4 mgpy |
| Alico/ Florida | Yard, wood wastes | Thermal/ syngas | Fermentation | 13.0 mgpy |
| Bluefire Eth./ S. California | Green waste, wood waste | Acid | Fermentation | 19.0 mgpy |
| POET/ Iowa | Corn stover, corn fiber | Base (NH3) | Enzymes, fermentation | 125 mgpy (25% cell) |
| Iogen/ Idaho | Wheat straw | Steam explosion | Enzymes, fermentation | 18 mgpy |
| Range Fuels/ Georgia | Wood waste, wood crops | Thermal/ syngas | Chemical catalysis | 40 mgpy |
| Mascoma/ Michigan | Hardwood chips | Steam explosion | Enzymes, fermentation | 40 mgpy |

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# Biomass Processing to Fuels: Estimated Production Costs for Mature Processes*

| Scenario | $/gal ethanol | $/gal gas equivalent | $/gal diesel equiv. |
|---|---|---|---|
| EtOH/ Rankine | $0.60 | $0.91 | na |
| EtOH/ GTCC | $0.63 | $0.95 | na |
| EtOH/FT/ GTCC | $0.72 | $1.09 | $1.02 |
| EtOH/Protein/ Rankine | $0.49 | $0.74 | na |

**At $60/barrel oil, gasoline wholesales for ~$2.00/gallon**

*From "Growing Energy:The Role of Biofuels in America's Energy Future" 2004 NRDC

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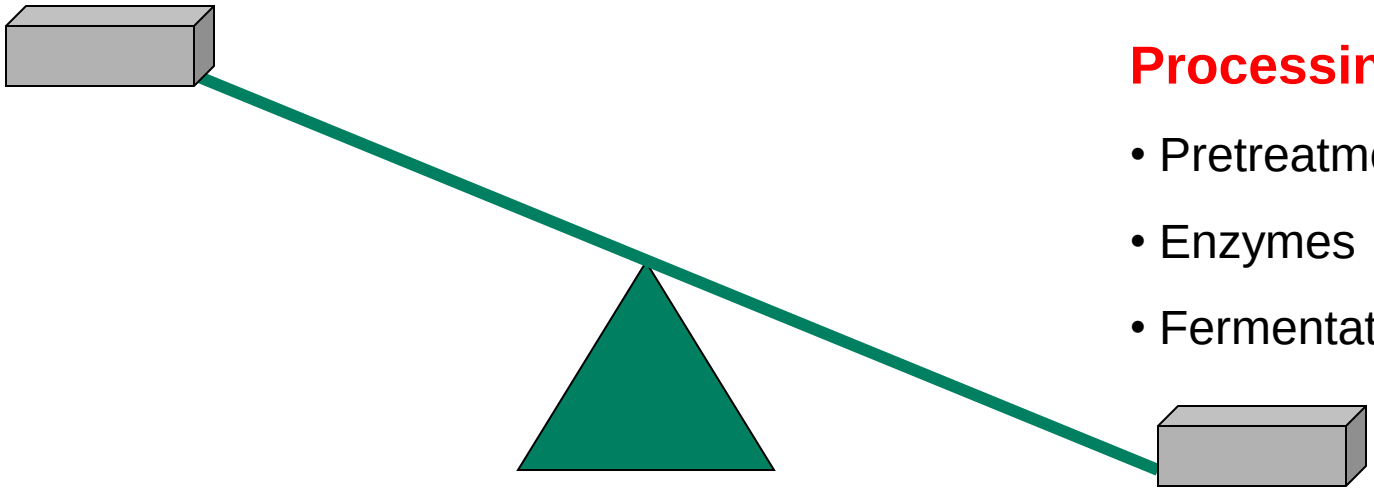
# Biofuels: Changing Balance between Processing and Feedstock

Today



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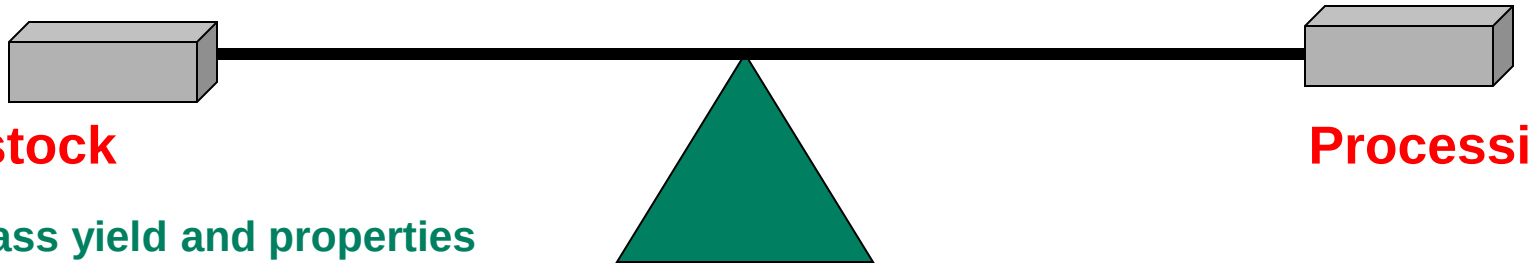
# Changing Balance between Processing & Feedstock: *Preparing for the Future*

## Near Future



**Feedstock** **Processing**

- **Biomass yield and properties**
- **Harvest/transport logistics**
- **Sustainability**
- **Rural economic development**
- **Co-products**
- **Many more!**

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# Planning for the Biofuels Future

- Premise: *the cellulosic biofuels industry will grow rapidly in coming years.*
- Some resulting questions:
  - How will supply chains develop—**big** issue?
  - How will society/interest groups, etc. react?
  - How will related environmental issues (carbon sequestration, water, soil quality, landscape values, biodiversity, etc.) be addressed?
  - What will the implications be for food/feed/fiber markets?
  - Can we coproduce fuels (& foods/feeds)?
  - How can farmers & local communities benefit?

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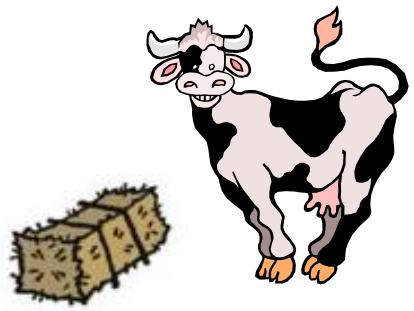
# Ruminant Animals & Biorefineries:

***Improve Cellulose Conversion for Biorefinery***
***= Improve Cellulose Digestibility for Cows***

Mobile Cellulose Biorefinery
(a.k.a. Cow)



=

Stationary Cellulose Biorefinery


Ruminant Bioreactor:

Biomass Input ~ 26 Lb/Day*

Capacity ~ 40 Gal Fermentor

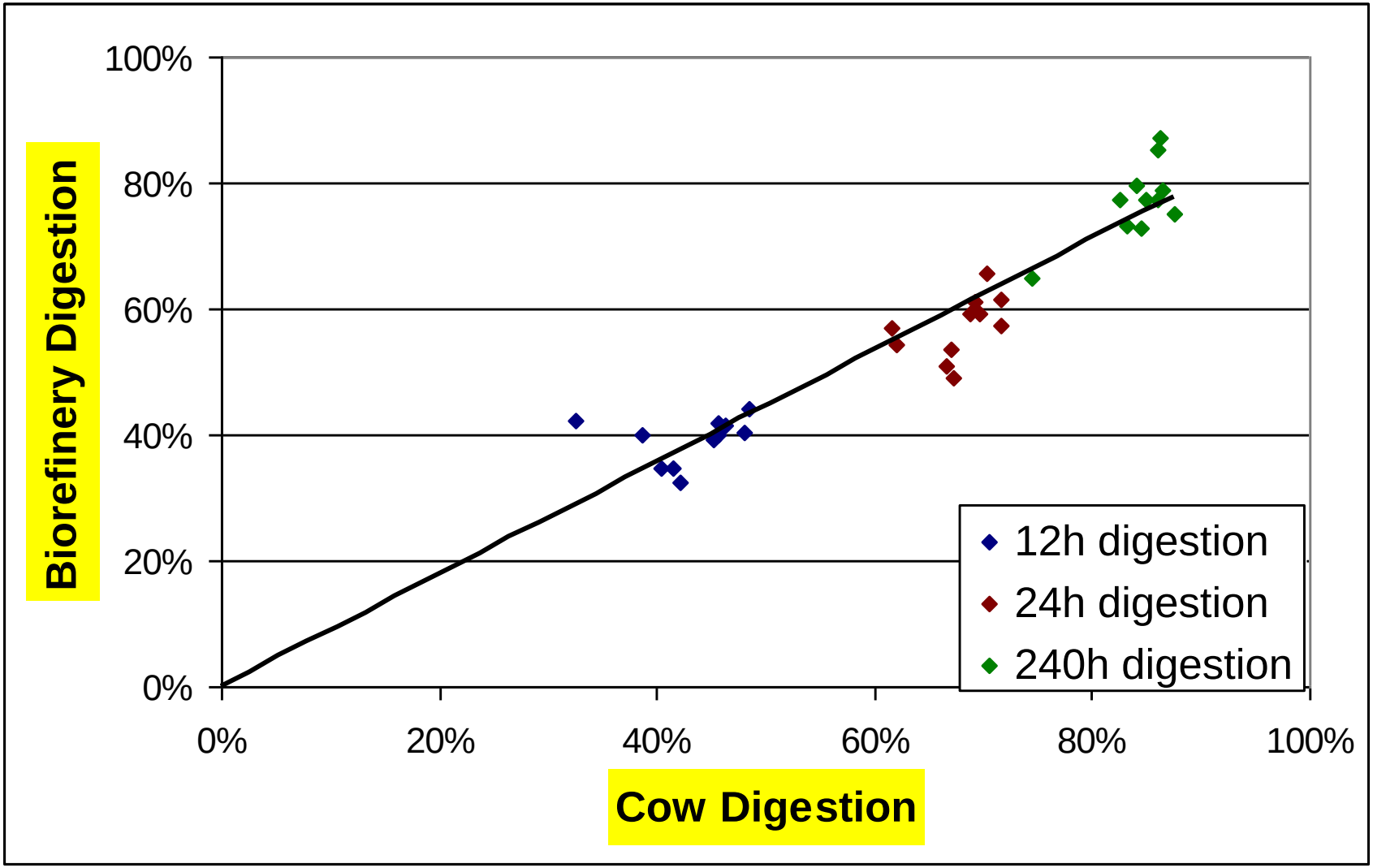
SSCF Bioreactor:

Biomass Input ~ 5,000 Dry Ton/Day
= 10 M Dry Lb/Day
Capacity ~ 45 M Gal Fermentor

*Cow is 3x more efficient than industrial bioreactor*

*Rasby, Rick. "Estimating Daily Forage Intake of Cows". University of Nebraska-Lincoln Institute of Agriculture and Natural Resources, http://beef.unl.edu/stories/200608210.shtml, 10/03/06

# AFEX-Treated Orchardgrass



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# U.S. Livestock Consumption of Calories & Protein

| ANIMAL CLASS | HERD SIZE (THOUSANDS) | TOTAL PROTEIN (MILLION KG/YR) | TOTAL ENERGY (TRILLION CAL/YR) |
|---|---|---|---|
| **Dairy** | **15,350** | **10,400** | **184.8** |
| **Beef** | **72,645** | **25,100** | **525.3** |
| **Hogs** | 60,234 | 6,900 | 136.2 |
| **Sheep** | 10,006 | 461 | 10.6 |
| **Egg production** | 446,900 | 2,470 | 4.3 |
| **Broilers produced** | 8,542,000 | 9,540 | 150.3 |
| **Turkeys produced** | 269,500 | 1,760 | 28.6 |
| **Total consumed by U.S. livestock** | | **56,630** | **1,040.00** |
| **Human requirements** | | **5,114** | **205** |

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# To support 20 people we need...


20 People = Our Lady Spartans and coaches

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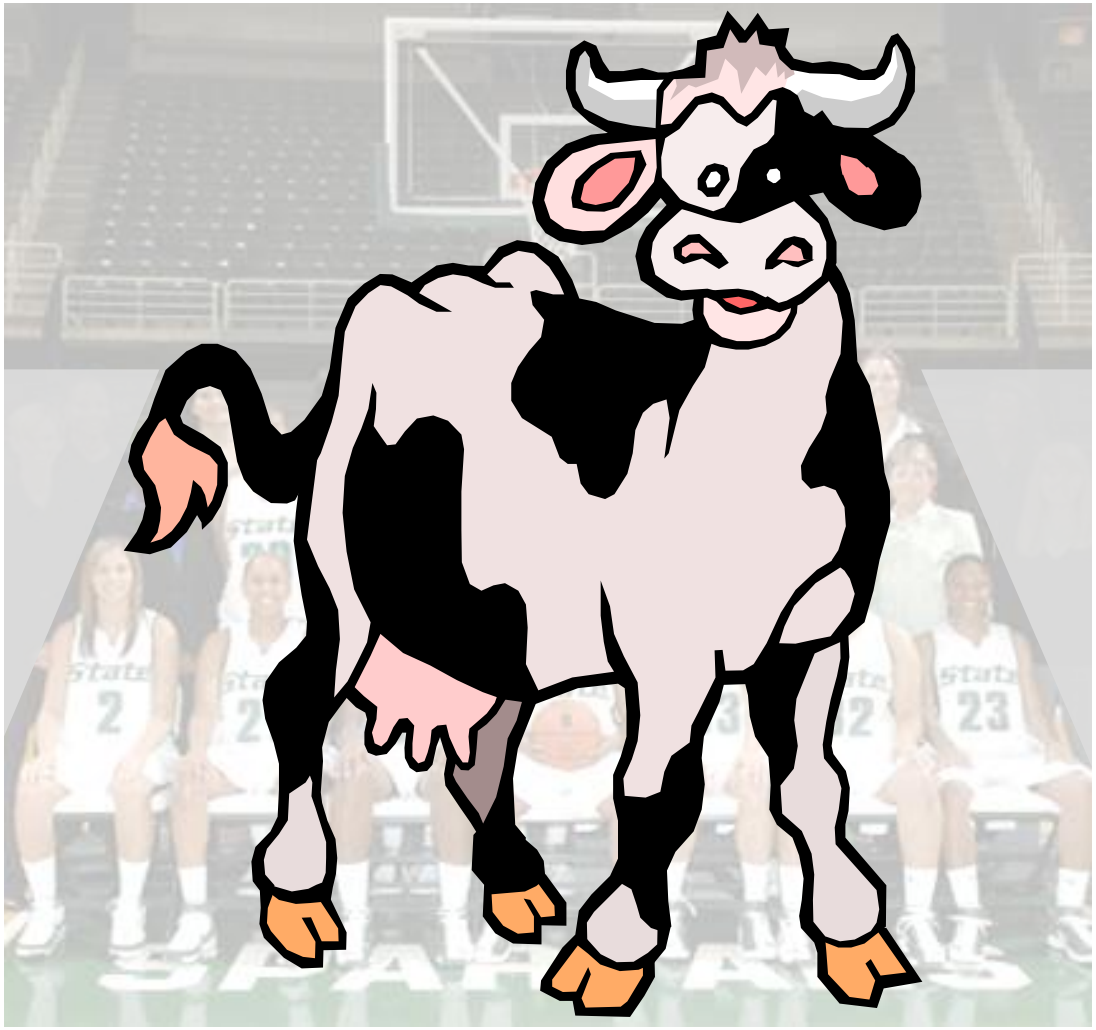
# Annual Livestock Production



20 people need 1 dairy cow

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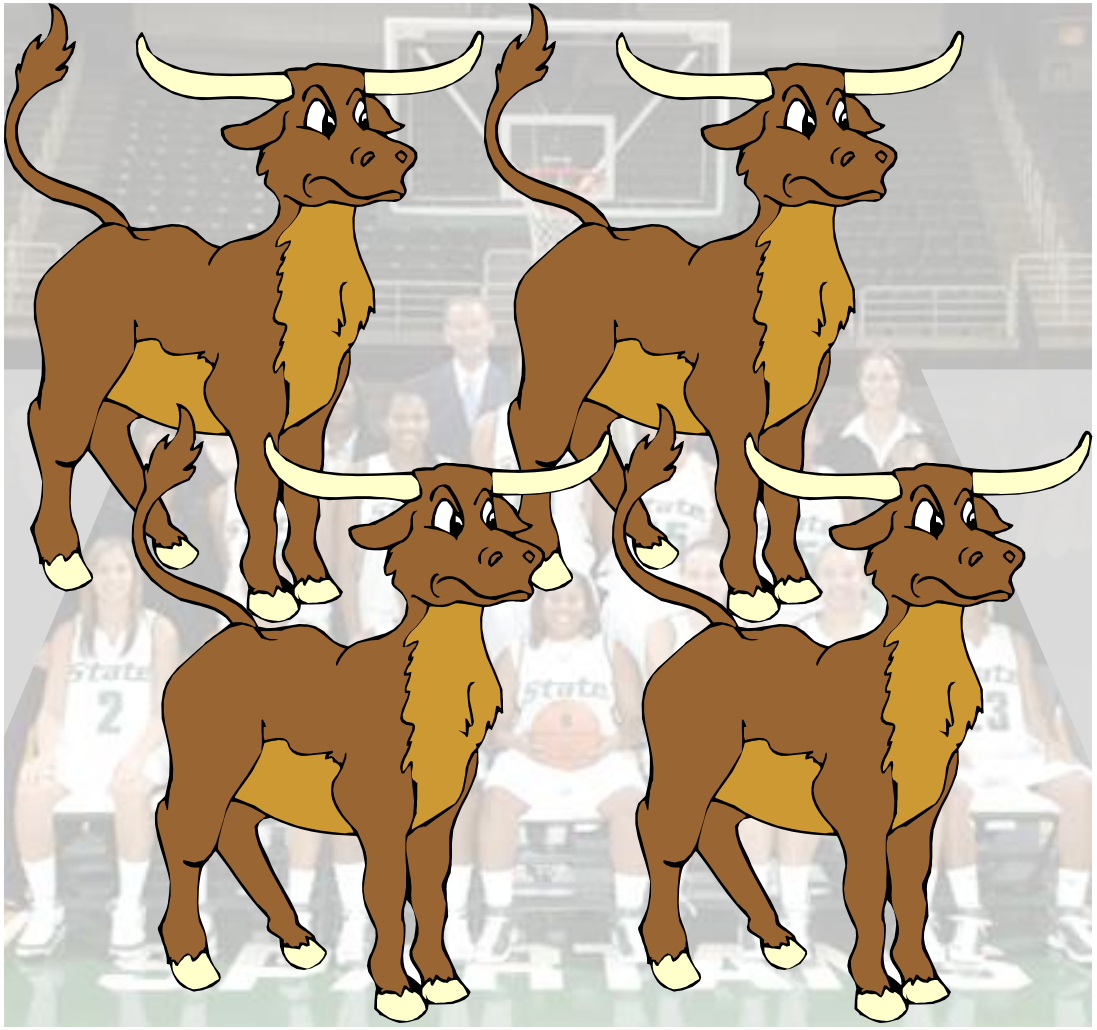
# Annual Livestock Production



20 people need 4 beef steers

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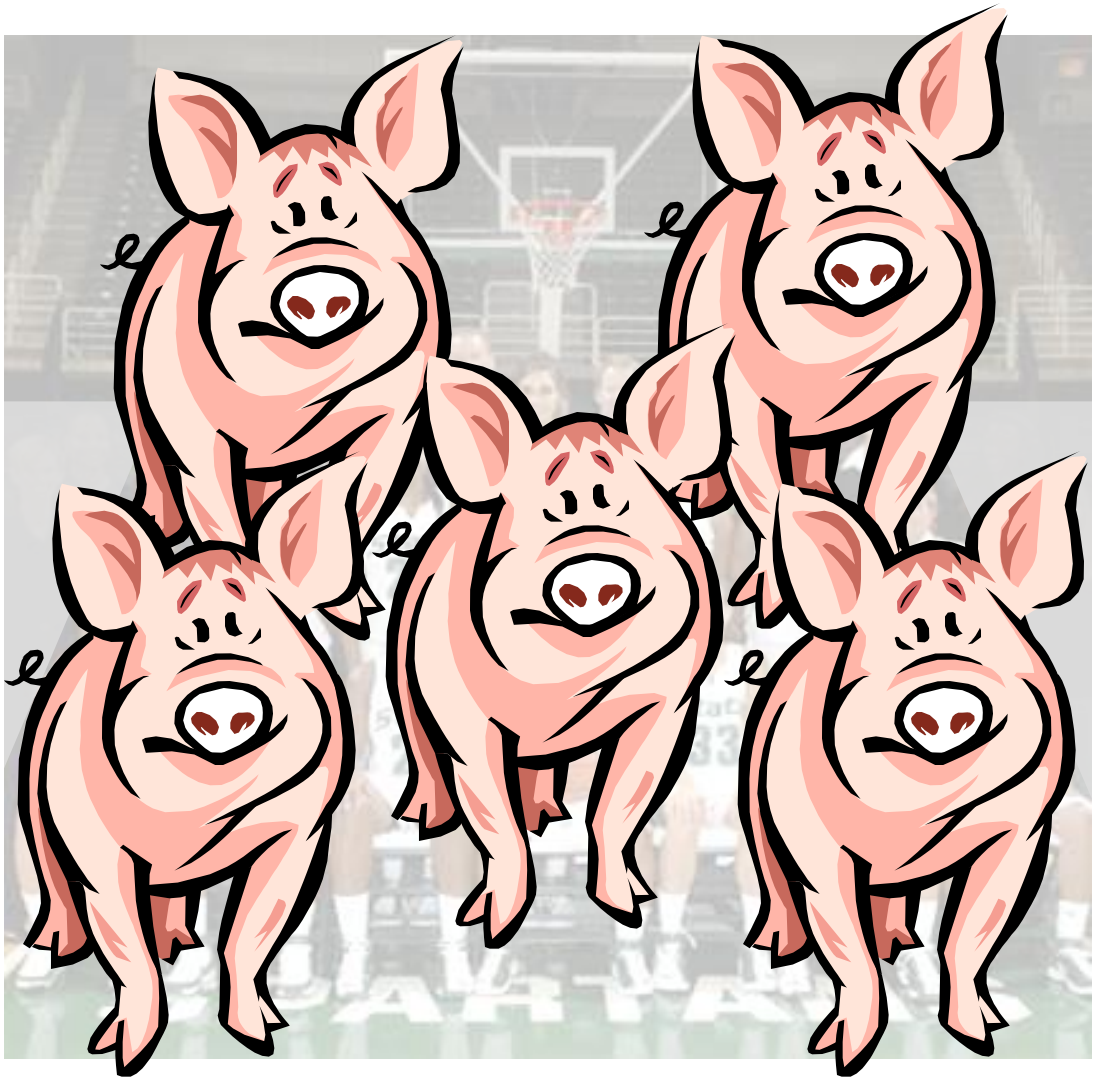
# Annual Livestock Production



20 people need 5 hogs

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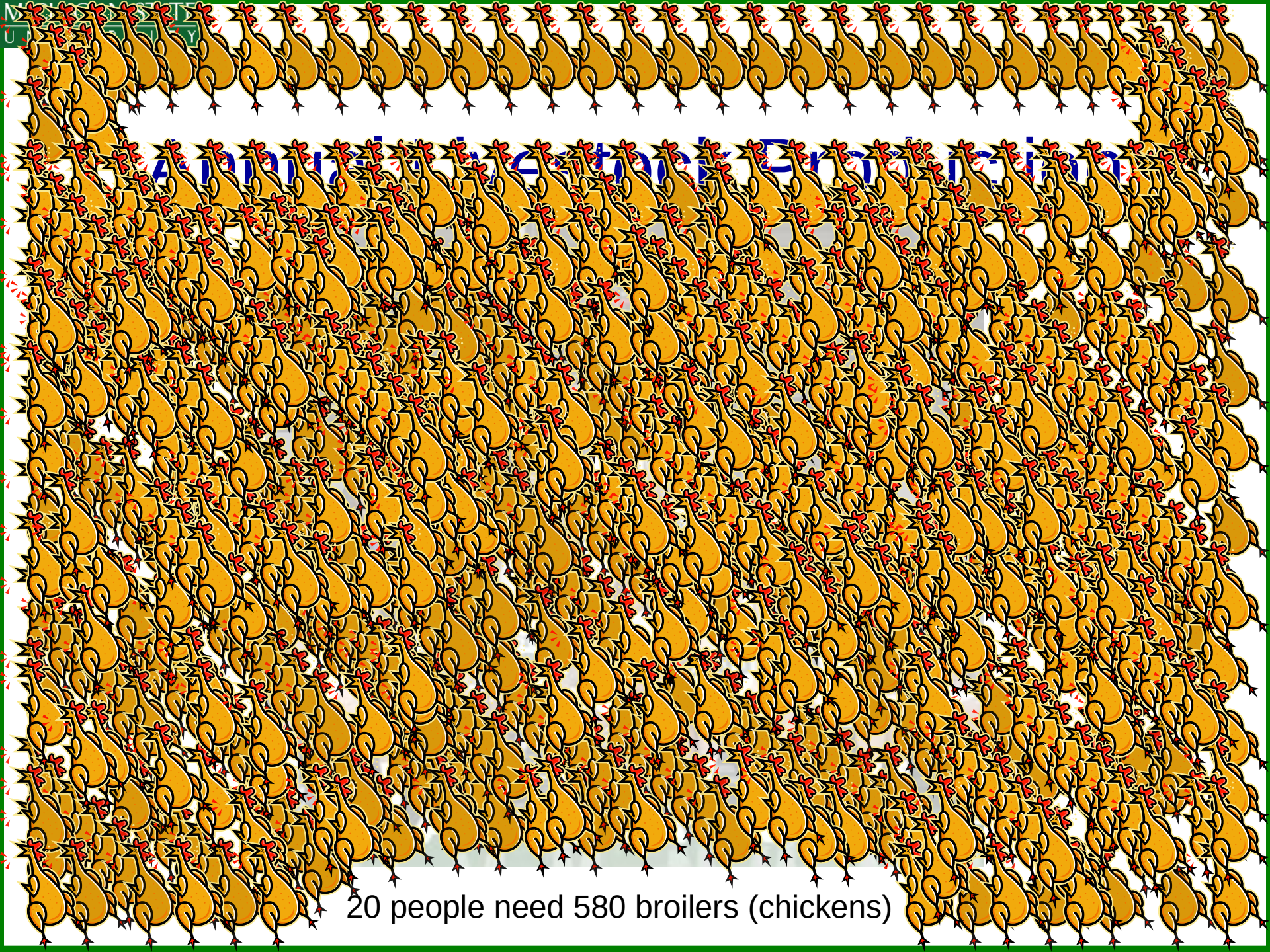
# Annual Livestock Production

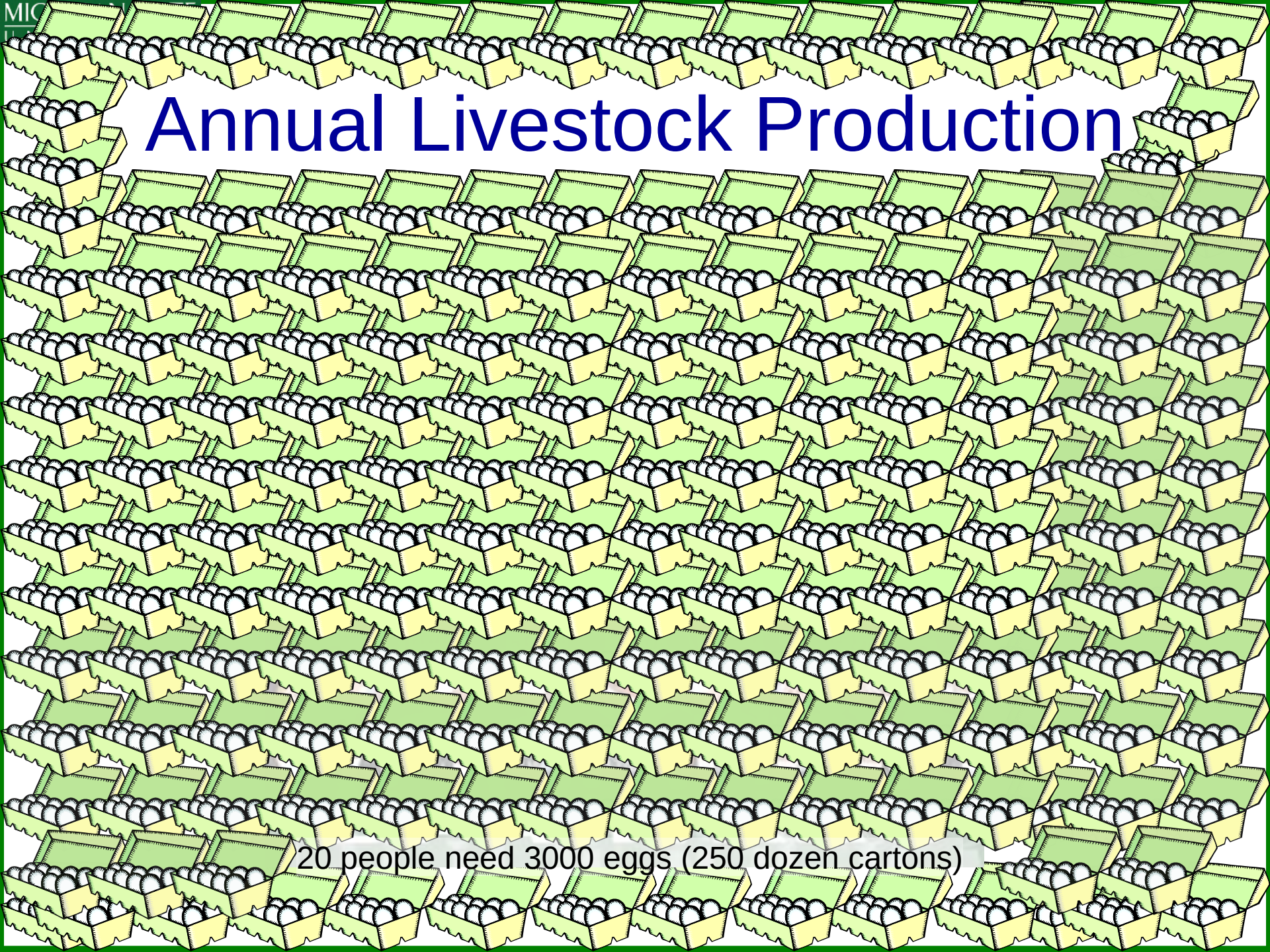
20 people need 20 turkeys

# Animal Science Extension Education



20 people need 580 broilers (chickens)

# Annual Livestock Production



20 people need 3000 eggs (250 dozen cartons)

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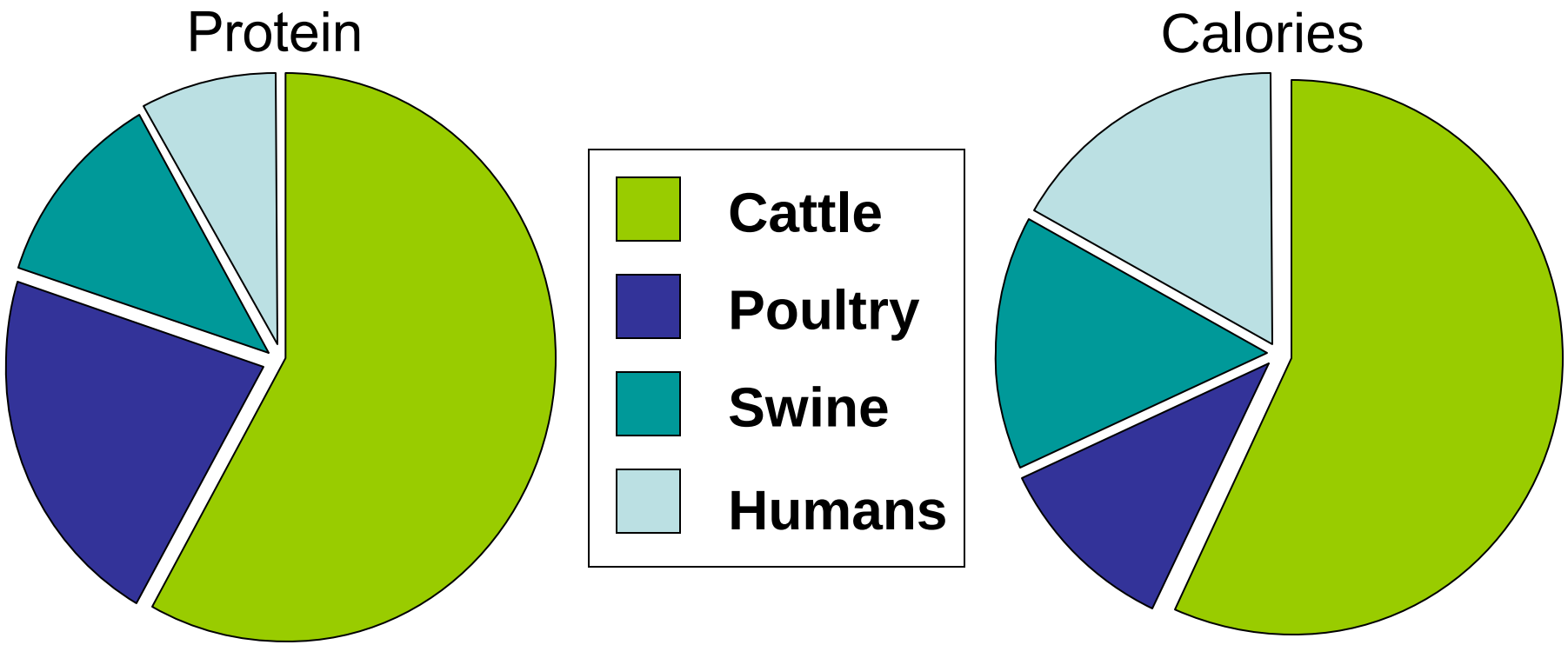
# Total Annual Consumption




- We don't grow "food"...we grow FEED!
- Cattle are the biggest consumers of both protein and energy feeds
- Reduce/remove "food vs. fuel" conflict by coproducing ruminant animal feeds and biofuels

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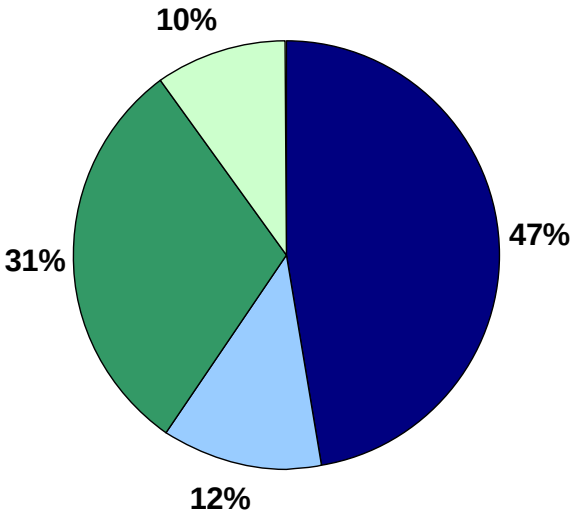
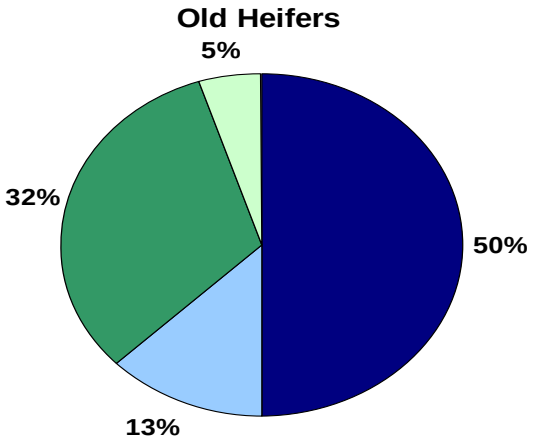
# Dairy Cows: Without AFEX Feed

Alfalfa Silage | Alfalfa Hay | Grain Silage | Dry Grain | Soybean Meal, 44%

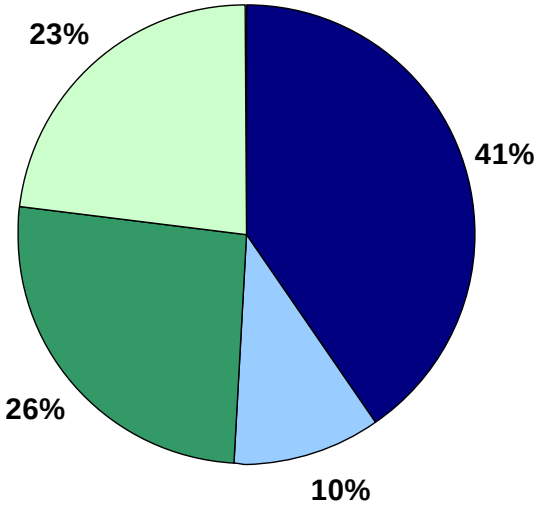
## Dry Cows



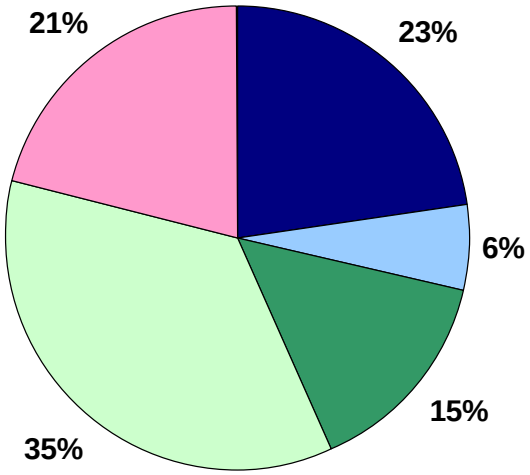

## Old Heifers



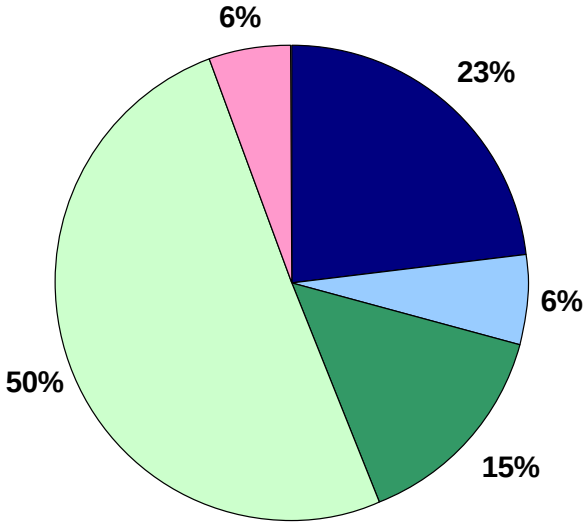

## Young Heifers



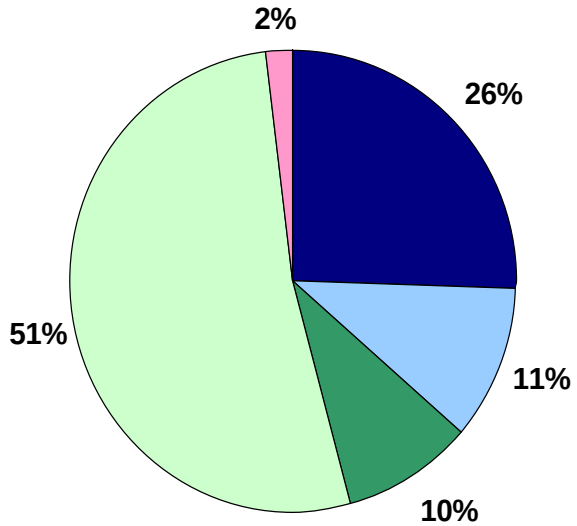

## Early Lactation Cows




## Mid Lactation Cows




## Late Lactation Cows



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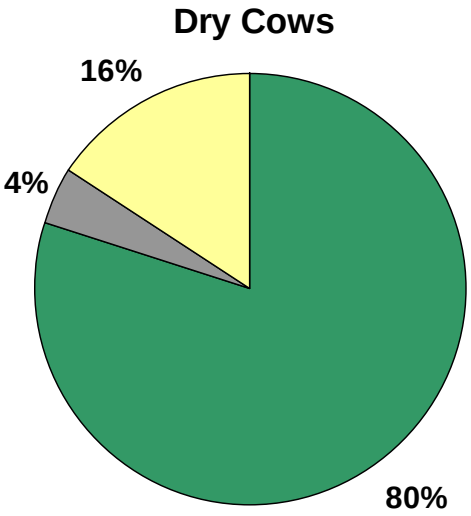
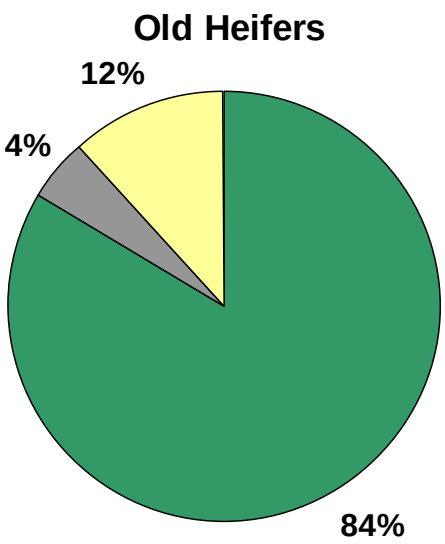
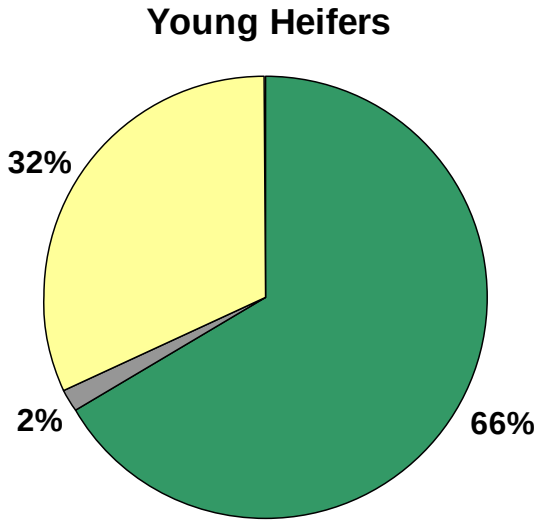
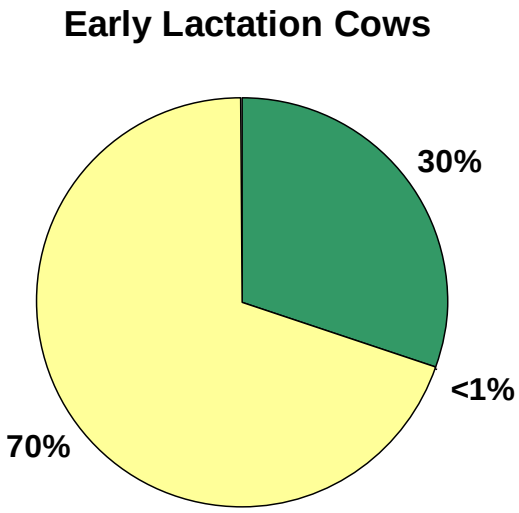
# Dairy Cows: With AFEX Feed

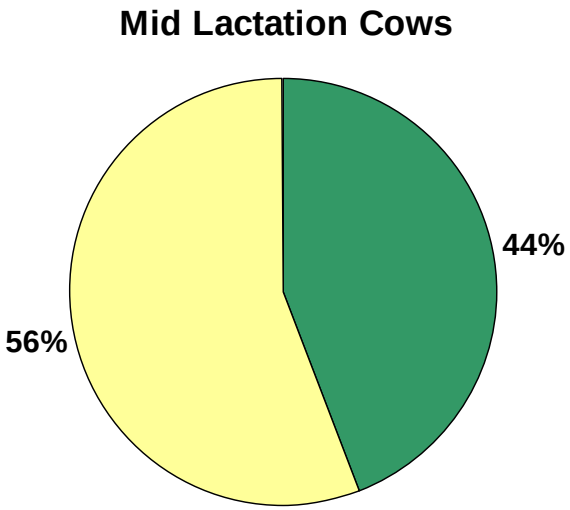
Grain Silage | AFEX Treated Switchgrass | Protein Supplement

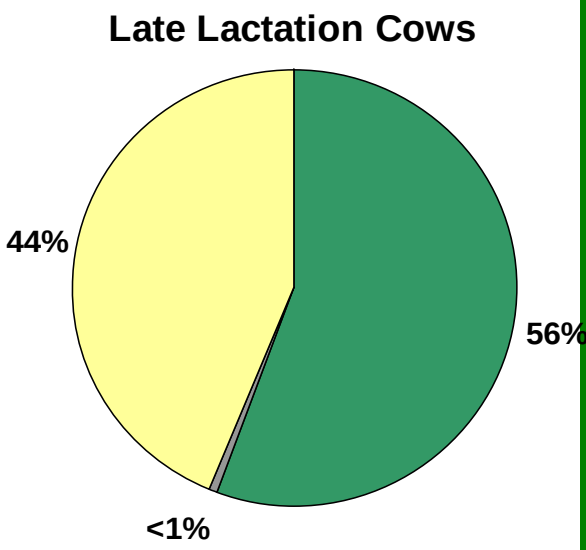



The “protein supplement” is a custom mix that would include a number of products with less rumen degradable protein (per CA Rotz)

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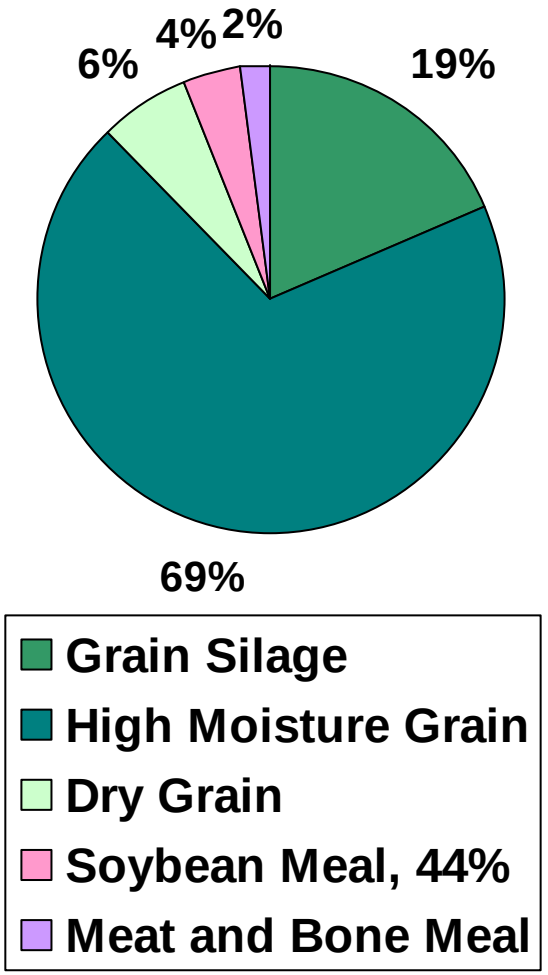
# Beef Cattle: Without AFEX Feed

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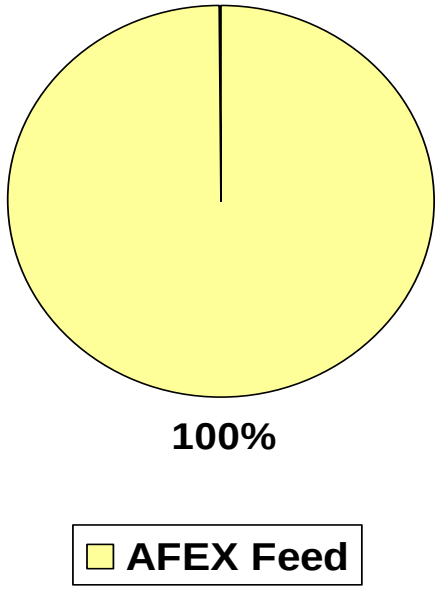

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# Grasses: Sustainable Sources of Protein & Calories for Cattle Feeding

Winter wheat cover crop

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# Thinking Ahead: Farmers & Biofuels

*"More than a century of bitter experience has taught farmers that when they simply sell a raw crop, they fall ever further behind."*

*David Morris "The American Prospect" April 2006*

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# Capturing Local Benefits from Biofuels

- Some issues for farmers/local interests
  - If farmers merely supply biomass, they will not benefit much from the biofuels revolution
  - Investment required for cellulosic ethanol biorefinery is huge ~ $250 million and up—difficult for farmers to participate
- Some issues for biofuel firms/larger society
  - Supply chain issues are enormous—need 5,000 ton/day from ~1,000 farmers: chemicals/fuels industries have zero experience with such large agricultural systems
  - Cellulosic biomass is bulky, difficult to transport
  - Need to resolve "food vs. fuel" problem: actually "animal feed and fuel opportunity"
- Is there a common solution?
  - Regional Biomass Processing Center– concept worthy of study
  - Pretreat biomass for biorefinery & ruminant (cattle) feeding
  - Much lower capital requirements—accessible to rural interests
  - Develop additional products over time—animal feed protein, enzymes, nutraceuticals, biobased composites, etc

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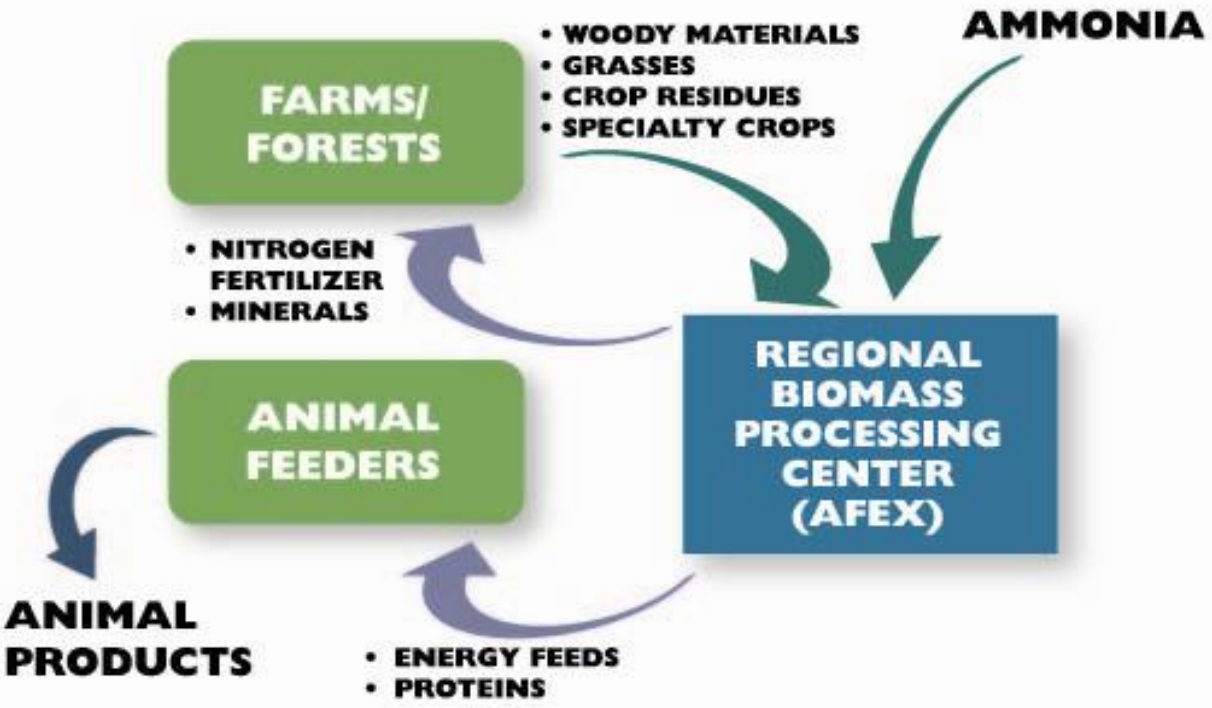
# REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



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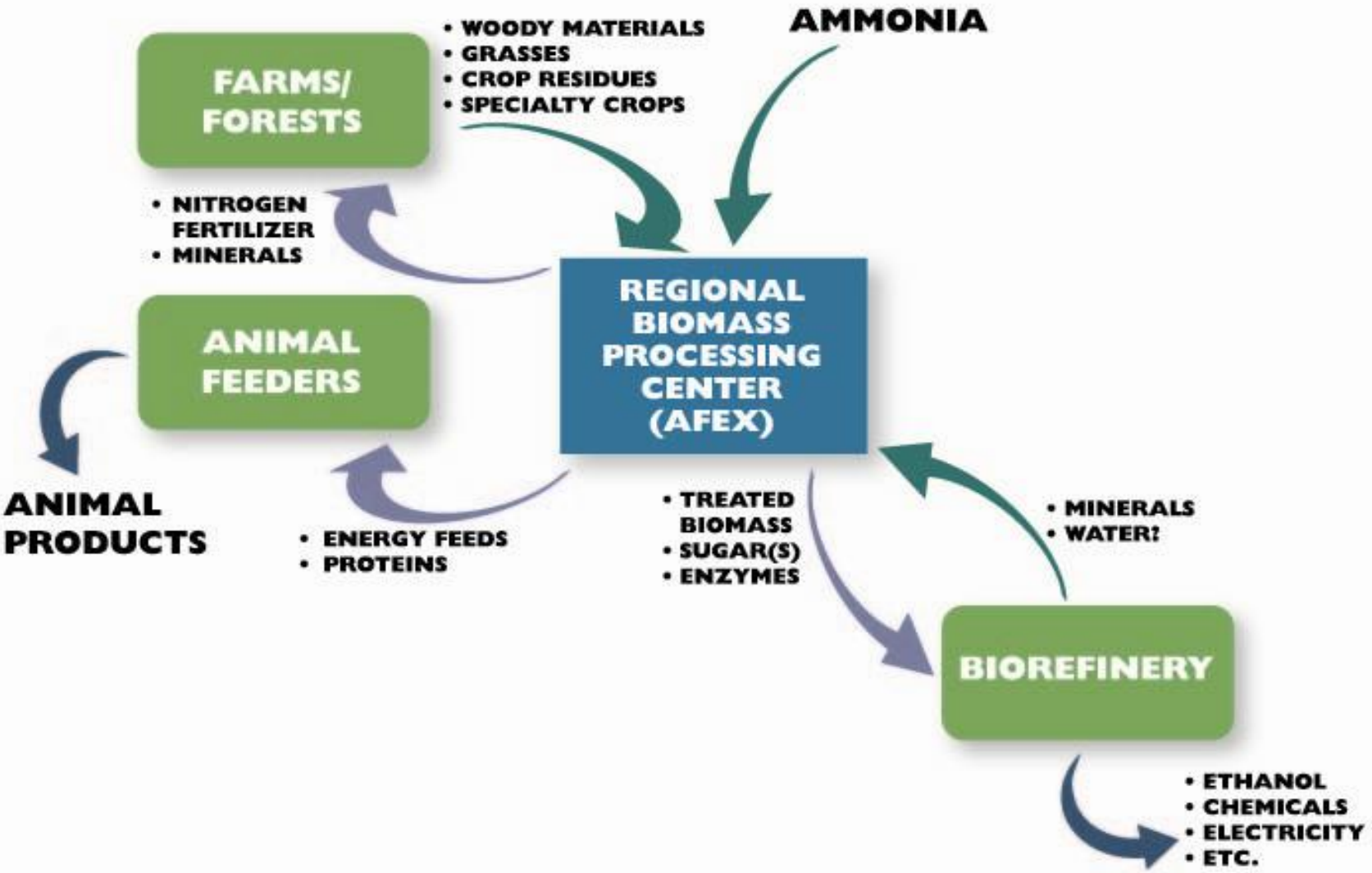
# REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



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# Why Regional Biomass Processing Centers?

- Concept: separate pretreatment operations from hydrolysis & fermentation (“distributed biorefining”)
- Pretreatment enhances value of cellulosic biomass for animal feeding and biofuel production
- Advantages:
  - Logistics: aggregate, process, store, supply biomass
  - Densify biomass for easier transport
  - Homogenize different biomass materials by pretreatment—draw on larger supply area
  - Increase economic scale of biorefinery
  - Simplify contract issues
  - Provide locus for economic development/wealth creation
  - Coproduce animal feeds and biofuel feedstocks
  - Increase land use efficiency of biofuels

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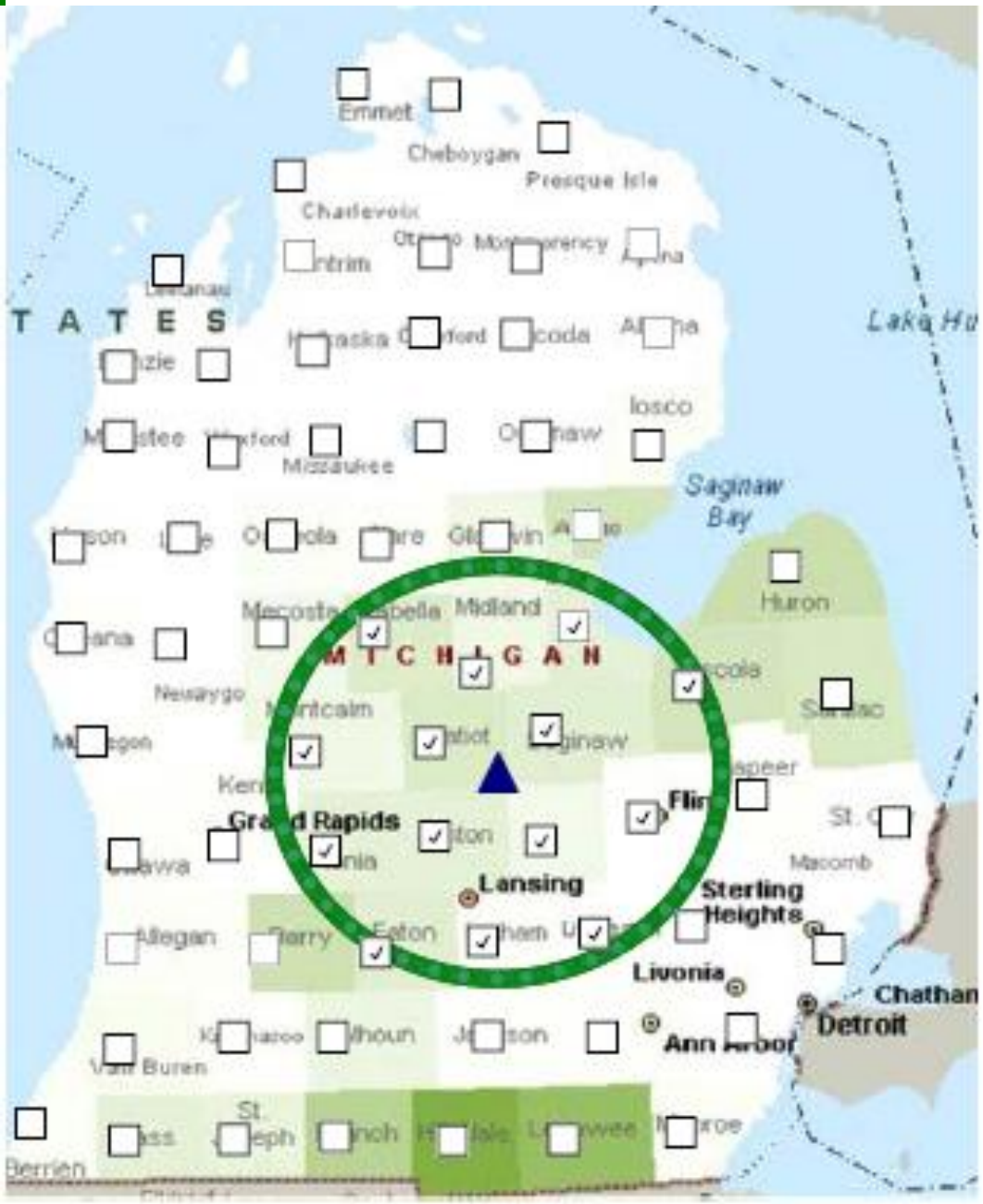
# Current thinking




***Nth Generation:***

- Fully integrated
- Small # per state (1 in MI)
- Limits to optimal size
  - Geographic:
    - Low cost biomass availability
    - Transport costs
  - Large # contracts to manage

***Potential Problems***

- Market Structure
- Supply Chain Logistics
- Sustainable rural development?

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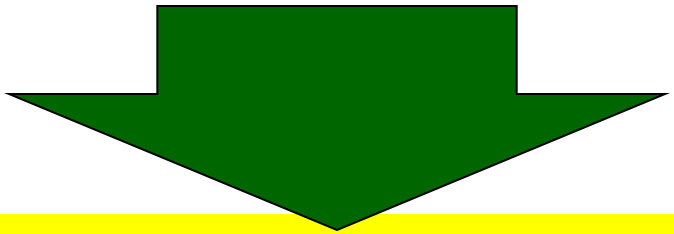
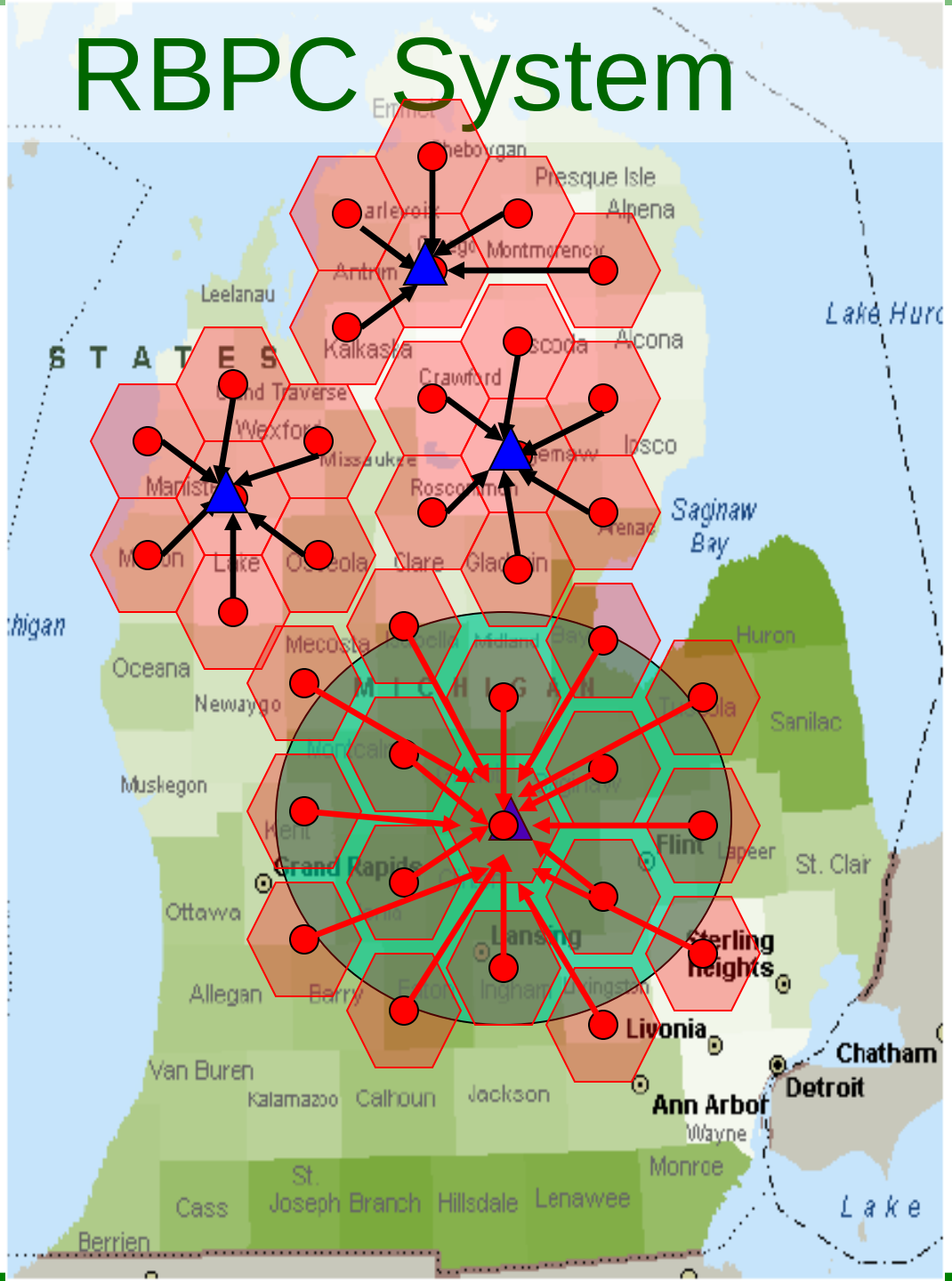
# RBPC System

Effect 1 – Larger Biorefineries in high yield areas

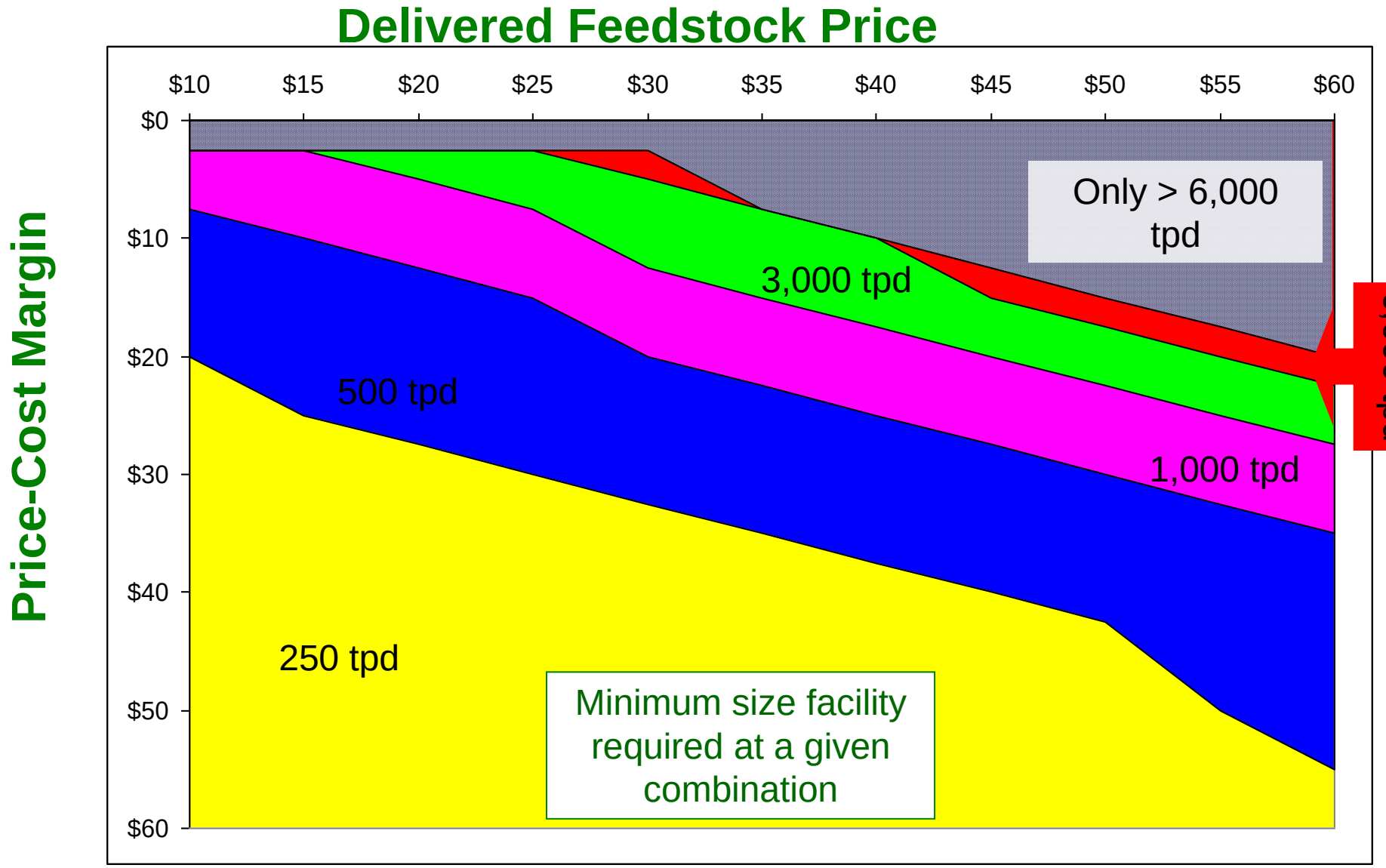
Effect 2 – biorefiners in remote rural areas



***Sustainable rural economies + Sustainable biofuels***



# Feasible Set of Feedstock Prices and PCM



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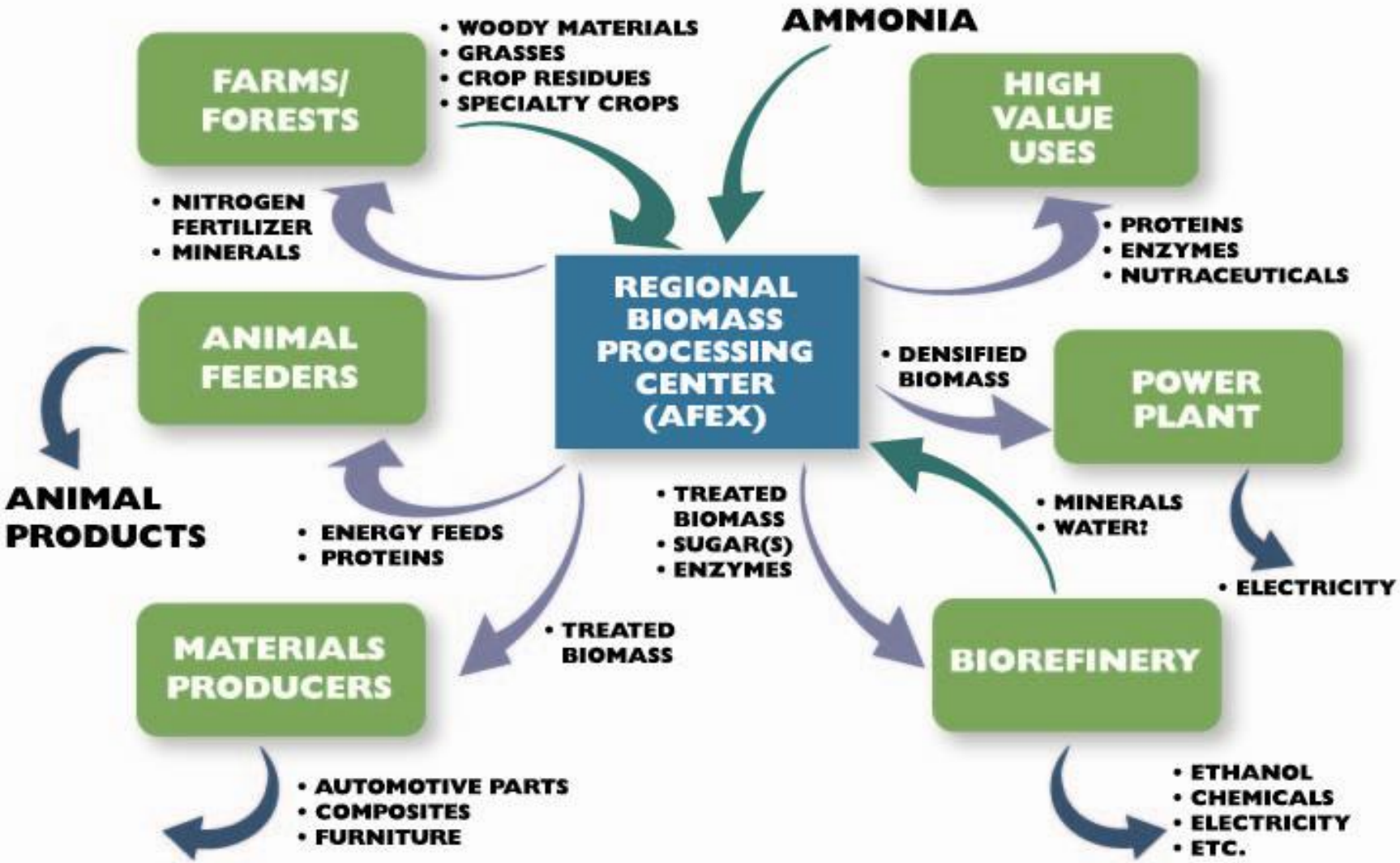
# REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



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# Improving the Sustainability of Biofuels: Corn Stover Removal & Cover Crops

- We want to harvest corn residue (stover) to make cellulosic ethanol & improve farmer profits
- However, corn stover removal will tend to reduce soil organic matter (soil fertility) & increase soil erosion
- This is not the right direction…
- *Is there a solution that allows us to remove stover sustainably?*
- Use winter cover crop
  - Plant cover crop (cool season grass: wheat, rye, oats) after corn harvest
  - Cover crop takes up excess soil nitrogen & phosphorus, grows rapidly in spring
  - Kill or plow under cover crop before planting next corn crop
  - *Or* harvest cover crop- we are now studying this option

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# Grasses: Improve Soil Quality & Reduce Nitrogen & Phosphorus Losses

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# Bare Corn Field- Holt, Michigan
# May 5, 2005

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# Improving the Sustainability of Biofuels: Corn Stover Removal & Cover Crops

- Basic cropping system
  - Corn (plow till) – soybean (no-till): CPSN (grain)
- Effect of winter cover crop under no-till corn continuous cultivation
  - 0 % of corn stover removed: CC (grain) (No cover crop)
  - Average 56 % corn stover removal: CC (56%) (No cover crop)
  - Wheat and oats as winter cover crops with 70 % corn stover removal : CwCo (70%)
- Effect of winter cover crop under no-till corn-soybean rotation
  - Wheat and oats as winter cover crops after corn cultivation with 70 % corn stover removal: CwSCo (70%)
  - Average 54 % of corn stover removed: CS (54%) (No winter cover crop)

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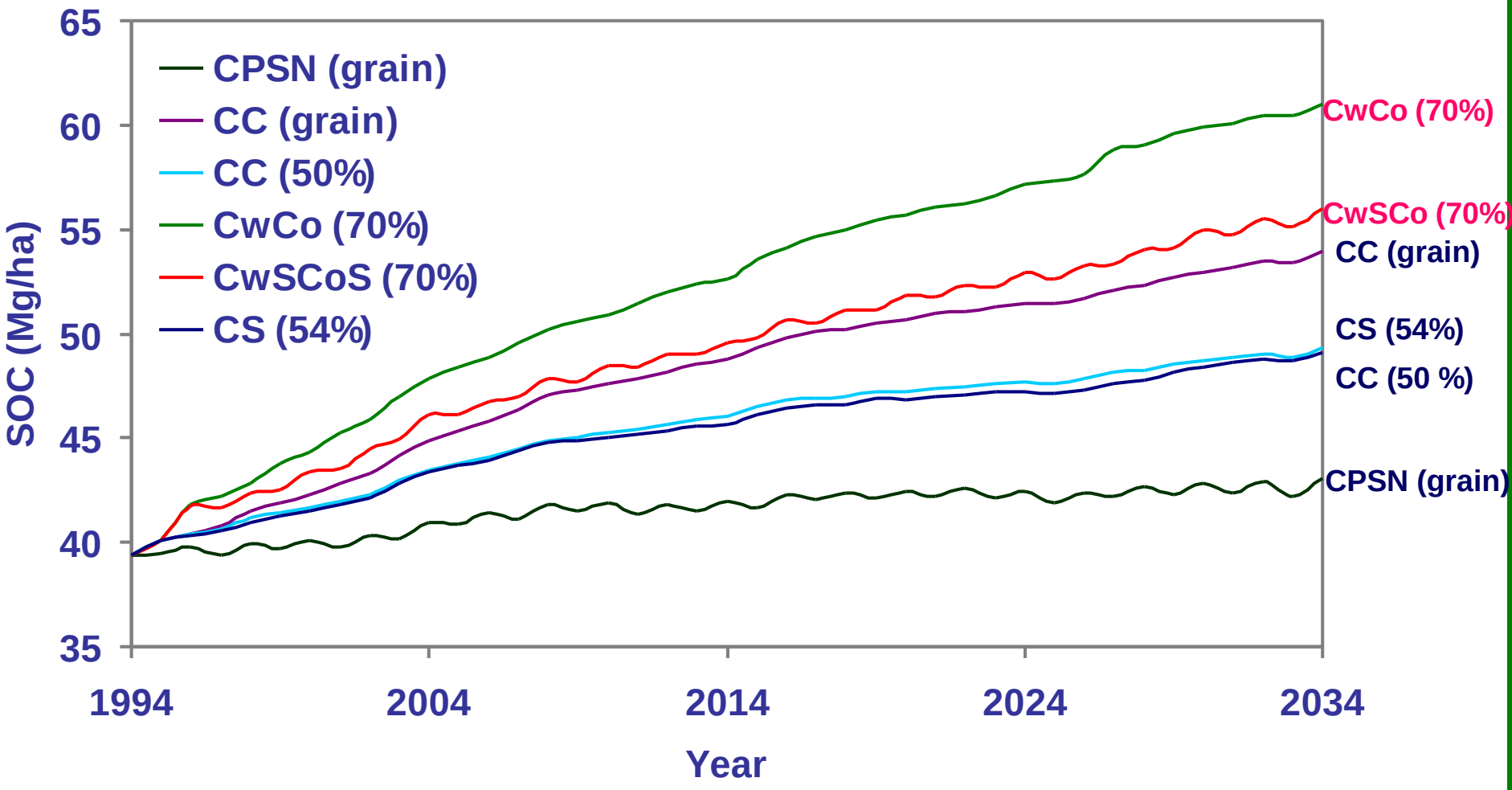
# Cover Crop Increases Soil Fertility While Still Removing Lots of Stover



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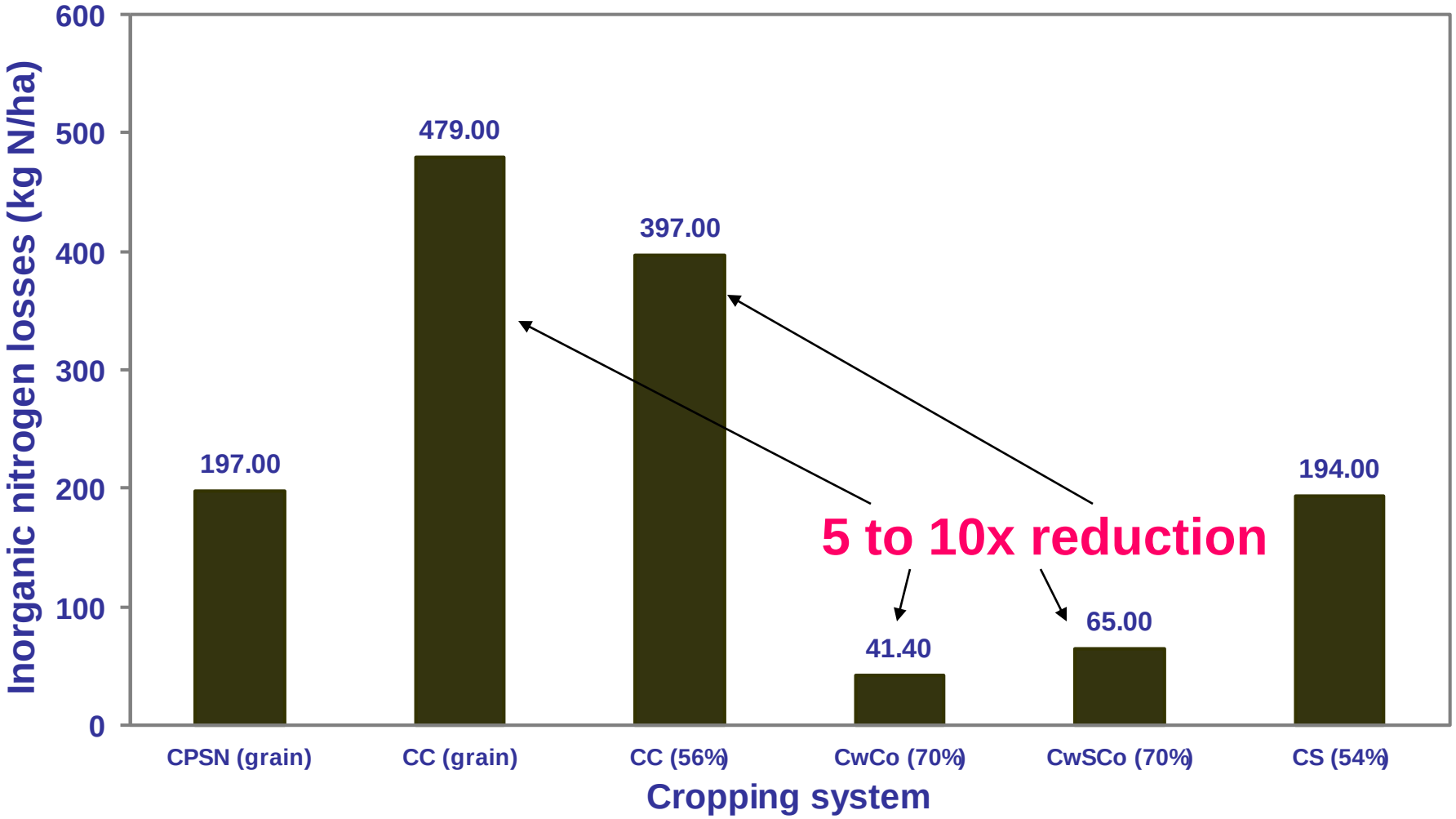
# Cover Crops Reduce Nitrogen Losses Tenfold*




*40 year time scale, Washington County, Illinois

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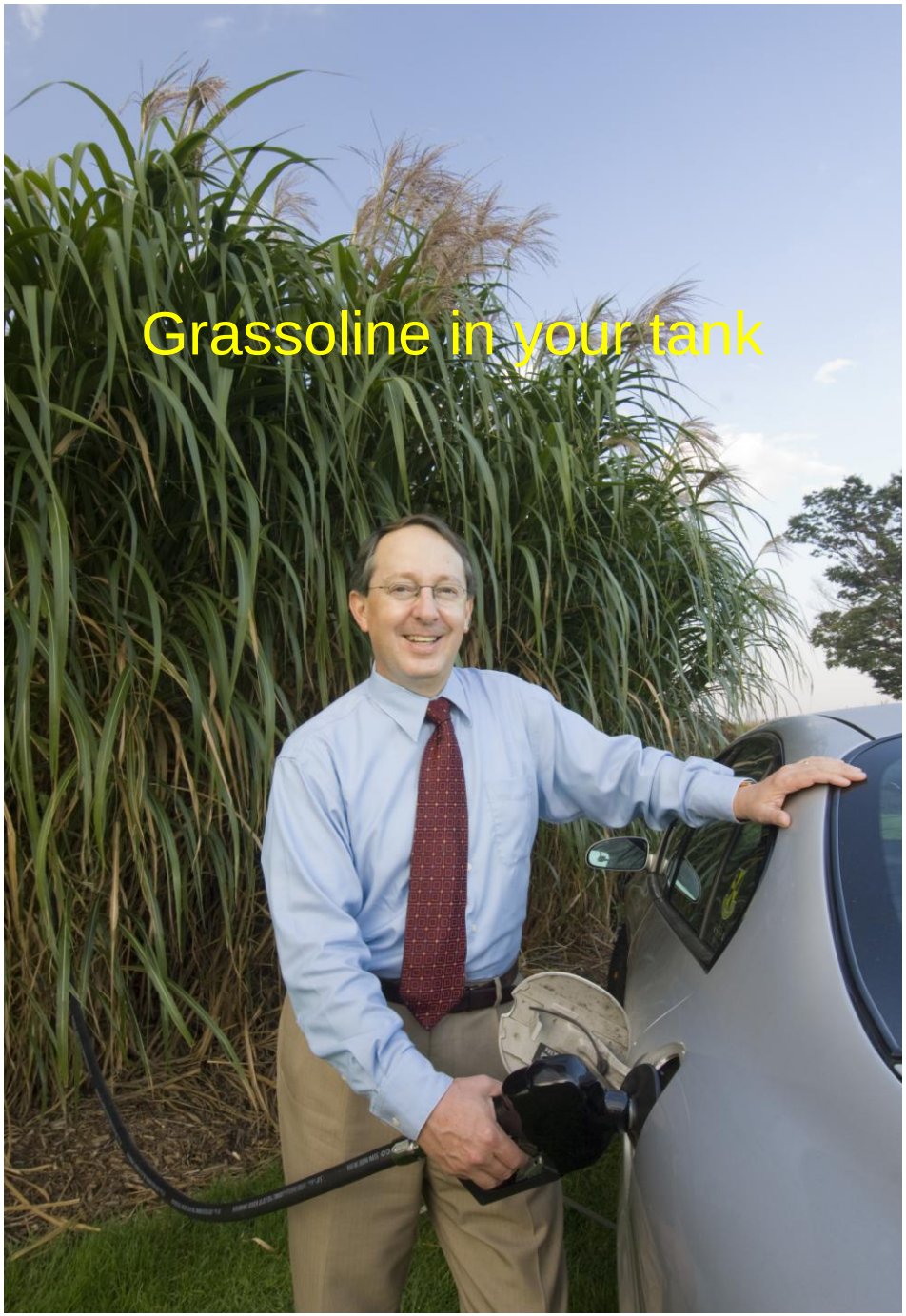
# What Happens Because of Inexpensive Ethanol?

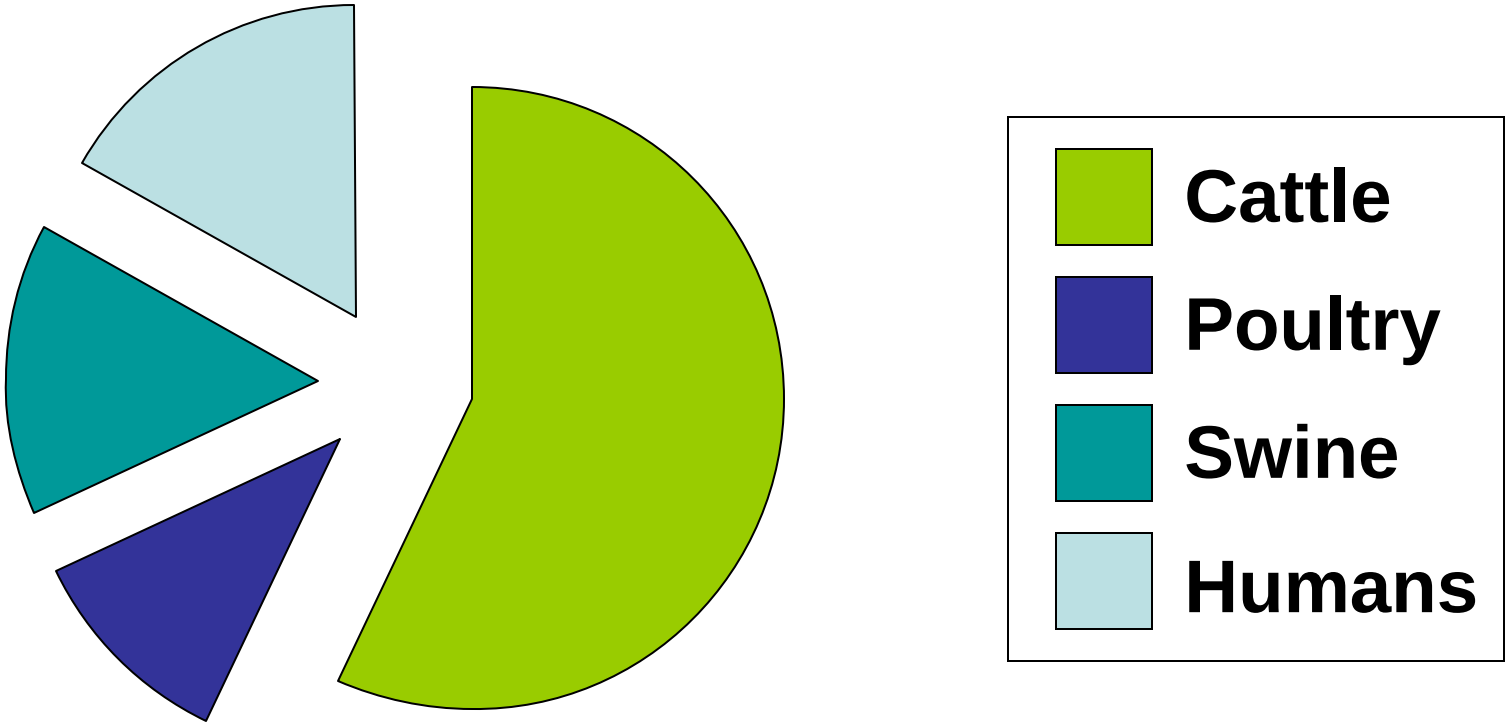
- Petroleum dominance declines
  - *Reduce petroleum's influence on prosperity & politics*
  - *Less chance for international conflict*
  - *Greater economic growth opportunities for poor nations*
- Environmental improvements possible – if we make it so
- Rural economic development possible – if we make it so
- Less expensive food possible – if we make it so
- ***The future is ours to create***

**“The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil.”**

**Sheikh Zaki Yamani**
**Former Saudi**
**Arabia Oil Minister**

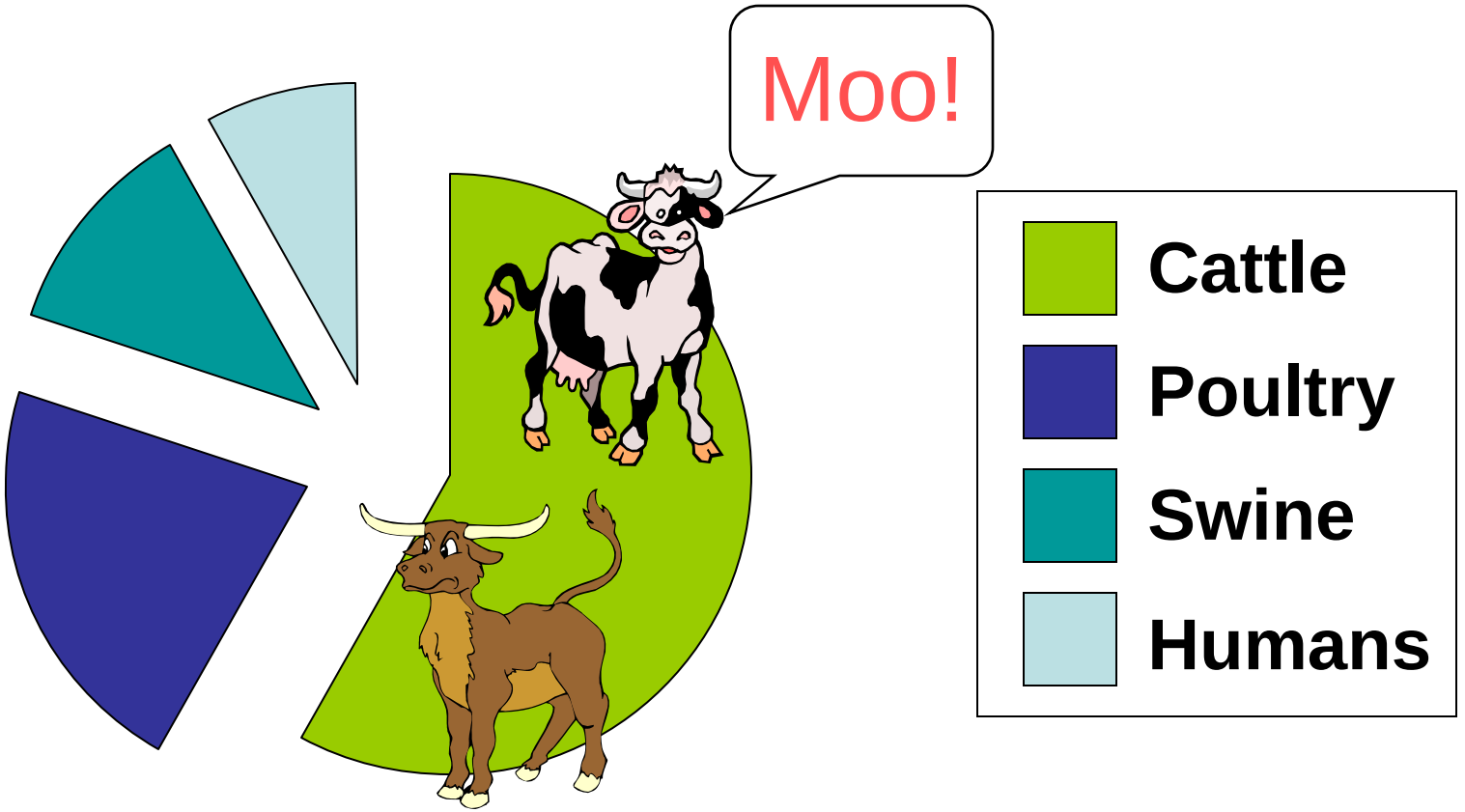


# Total Annual Calorie Consumption




Similar trend, cattle dominant

# Total Annual Protein Consumption




Beef and dairy cattle are the “big dogs”

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# Ethanol Production Flowchart